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COLLEGE GRADUATES.

BY JAMES P. MUNROE.

THE word, college, in the title, is used in a somewhat contradictory sense. It is intended to cover more and yet less than its usual meaning. University would be better, were it not that this term has hardly, as yet, obtained foothold in this country. Despite the adoption of the title by several of our institutions for higher learning, the university, in its full European significance, does not exist on this side of the Atlantic. On the other hand, the term, college, is too comprehensive. No proper distinction is made, in the United States, between the real college, the institution for training men in letters and the arts, and the secondary institution, the academy, seminary, or high school, which, with no semblance, except nominal, of a collegiate scheme of instruction, usurps the title.

Indeed, the standards of thought are so different in the several States of the Union, the grade of scholarship which shall be rewarded by a bachelor's or a doctor's degree is so indeterminate a thing, that it is quite impossible to define a college. It is sufficient for the present purpose to include all institutions, classical, scientific, and professional, in which the full course occupies three or four years, and for which the minimum of preparation is that offered by a New England high school of average grade. For convenience, the general term, university, will be used to designate such institutions.

In so grouping and generalizing them, however, it should not be forgotten that the whole is used to designate the part, and that the func-

tion each performs is widely different from that of the others. The college proper (based mainly upon the classics), the scientific school, and the professional school have little in common. The first is, as a rule, a vehicle for culture, a means solely of fostering, enlarging, and cultivating the mind. As such, it is the natural forerunner of the schools of law, medicine, and theology. For this reason, because of the customary sequence of collegiate and professional instruction, the latter is, as a rule, narrow in its scope and undiversified. He who comes for it, otherwise than through the gates of the college, must look elsewhere for his general culture. Here he can be perfected only in the wielding of the tools of his profession. In this point, and for this reason, the technical and trade schools might be included among professional institutions; but from necessity, from the very nature of the occupations taught, these institutions are on a lower plane.

The scientific school, however, stands in entirely different relations to the community. It is, of course, an outgrowth of the age, demanded by the inventive genius, the wealth of resource, and the industrial activity of the country; but it is, in a measure, the product of the revolt against the too exclusive classicism of the colleges, a revolt which already finds its reflection in the colleges themselves. The advance of scientific training has been hastened, its possibilities have been developed, and its footing strengthened, by the demand for an education which shall have a somewhat closer relationship to men and things of to-day, than it is possible to create through the medium of an acquaintance with dead languages and outworn systems of philosophy.

The scientific school might have taken its place with the professional institutions, thereby confining itself, chiefly, to those seeking it after the completion of the orthodox training. It might perhaps, on the other hand, by limiting its scope, have taken a rank but little above that of the technical or trade school. Instead of this, it has assumed, and to all evidence has secured, a place of equal footing if not, indeed, of friendly rivalry, with its classical elder sister.

In doing this, however, in assuming this position of equal honor, it has taken upon itself an immense responsibility. For it must in no wise neglect the professional training. The bachelor of engineering must be no whit less finished than the bachelor of law and the doctor of medicine. At the same time, the burden of general culture, which in the professional schools is not assumed, being shifted upon the shoulders of the college, must, in the scientific school, be taken up and carried to the best possible result. A twofold problem is presented, and is made doubly hard by the difficulty of keeping due proportion

and balance in the minds of its students. The college and the professional school can each command the attention of its pupils to the one species of training; the latter has, moreover, the enormous advantage of dealing with minds of greater or less maturity. The scientific school, on the other hand, must take young men, immature as a rule, ambitious to devote themselves to their several specialties, interested more and more deeply in the problems of their ever-developing professions, and chafing constantly against the curb that must be set against the overbalance of training without cultivation, and must lead them to the same general result as is achieved by the college. It must give them, in equal degree with that institution, the something which distinguishes the college man from him who has not had a university education.

Putting aside the vexed question as to whether or not the college and the scientific school do train men to the same result of culture, and eliminating from the discussion men who must, by the very nature of their subsequent occupations, either as scholars, physicians, lawyers, architects, or engineers, choose, without question, between the former and the latter, wherein does he who has been graduated from one or another of the higher institutions of learning differ from his fellow, of equal mental capacity, who has not had similar opportunity? In what is the first man better or worse than the second? What is the *something* distinguishing the one from the other? Why should a boy of seventeen or eighteen, who has no intention of entering professional life, be allowed to spend four or more of his most active years in training himself in directions bearing only remotely, if at all, upon his work in life? Does he not lose rather than gain by being switched off, so to speak, while his fellows out of college are plodding along in the rudiments of mercantile and other "practical" pursuits?

The attitudes taken toward these questions by those outside the universities are seldom unprejudiced, and are, usually, violently in opposition. One class view the university with extreme hostility, holding it responsible for much of idleness and wickedness in the world, while their opponents go to the other extreme and make a fetich of collegiate training, believing its graduates to be equipped with a magic wand to open all doors and clear away all obstacles. The second attitude prevails especially among men who have had to deny themselves this training, but for whose sons it is a possibility and almost *summum bonum*.

The opponents of the university, in considering the expediency of college breeding, will say, at once, that a boy so brought up is put at an

immense disadvantage, by wasting, as they will term it, the best acquisitive years of his life in the pursuit of knowledge bearing, at best, but indirectly upon his subsequent career. They will maintain that there will result stagnation, or, in all probability, something worse from those four or more years. They will assert that the small increase of knowledge which may come to a young man in his college career may be quite as well attained in addition to and coincident with his mercantile or administrative life; that if a boy is worth educating, if he has any inherent desire for acquisition and growth, he will cultivate himself, saving thereby the four precious years which would otherwise be almost wholly sacrificed.

In support of their thesis, they will instance the fact that a college graduate, as such, is good for nothing in business, that he can take no higher place at twenty-two than would have been his at sixteen years of age; and they will maintain, furthermore, that his college life and habits have unfitted him to assume, to the same profit to himself and his employers, at the greater age, the position for which he was perfectly prepared at the lesser.

There is, unfortunately, evidence to support this view of the question; there are young men, and perhaps their number is not small, upon whom a college course seems to be a life-long drag; who, without it, might have risen to honorable position in the world; but upon whom the bachelor's degree has set a stamp of hopeless mediocrity. The difficulty here is not, it seems to me, except in a measure, with the university training, but with the man himself. With rare exceptions, no boy should be cultivated, beyond a certain point, against his will, or against the indisputable evidence of his incapacity for real benefit from higher training. Nature is too strong for custom to profitably war against her. Wrong as it may seem to deprive a boy of advantages which might be his, were it not for his refusal of them, bitter as it is to yield your way to the boy's way, the fruit of a forced acceptance on his part will be bitterer still. His revolt against his own best interest may be inborn, it may be the fault of early errors in training; in either case it cannot be overcome by coercion; it must be accepted, at once and finally. It is, largely, such boys and the unhappy results of their forced training that lend color to the assertions of the enemies of the university, and that almost lead one, sometimes, to agree that collegiate education is fitted only for the few.

A second class of university failures is the result of the systems and methods of instruction holding in many schools, both secondary and collegiate. It often happens that, owing to false notions of teaching, a boy

never discovers, from the time of his entrance into school life to the day of his issuing from the college doors, that education is anything else than a prescribed routine, of which he must take up, in order, the several steps; a sort of algebraic process involving formulæ to be memorized, but by no means understood, and by a juggling use of which a certain desired result will be brought about. That education means training, that the acquisition of one subject after another has any bearing upon his future life, except in so far as it does or does not give him a title and a certain social status, never enters his mind. This is not the fault of the boy. The "educational mill" is wholly responsible. It grinds, year in and year out, receiving so many untaught boys at one end and turning them out, in a variable number of years, at the other end, finished. And *finished* indeed are most of them, so far as any usefulness to the world is concerned. In the ten, fifteen, or twenty years during which they have been laboring through the meshes and convolutions of the educational machine, their minds have never once been appealed to. Their memories have, in all probability, been abnormally developed, and a kind of facility in jumping at conclusions has been aroused, but they are no more fitted to reason, their five senses and, above all, their common sense, are no more acute, at twenty than they were at five years of age. In fact, these precious senses and this indispensable common sense have actually been dulled, cowed, and made in a degree inoperative, by their journey through this monstrous educational mangle.

A third class of boys who are hurt by a collegiate career, and, unhappily, this class seems to be on the increase, is made up of those who, while they have good instruction, and may, at the start, be apt and ambitious, are sent to a university not to learn, not to be developed, but solely to attain the prestige, the social distinction, supposed to accompany the possession of a collegiate diploma. Everybody about these young men insists, not upon the mental and moral benefits of education, but wholly upon the social advantages of it. Naturally, the plastic mind of the boy accepts this pleasant view, and he employs his talents and his ambition only so far as may be necessary to secure the social stamp, the seal of good breeding, which is the reward of a certain number of years of apprenticeship in the schools. He buys, or his parents buy for him, through the necessary expenditure of money and time, the educational crest, the emblem from the college of letters, in the same spirit and with no more feeling of wrong or shame than is aroused by the purchase of a coat of arms from the college of heralds.

It is chiefly through this foolish boy and his more foolish relatives

that the scandal of luxury, with its attendant evils, has come to the higher, and indeed, to the lower, educational institutions. The worship of money, the love of display, the extravagance and wastefulness that are the natural product of the times, have not spared even the boys. The youth still in his minority is trumpeted through Vanity Fair, and, with their approval, must imitate his elders in their silly, tinsel progress through the world. The sturdy independence of the genuine boy, the better sense of the majority, can alone put a stop to this unpleasant and, it is to be hoped, transient phase of college life. So long as the unwritten code of college ethics holds, so long as the richest student shall not, of necessity, be the most popular student, the life of the university is not threatened by an invasion of luxury. But woe to the college, and woe to the nation, whose boys lose their independence and singleness of heart. "The nonchalance of boys who are sure of a dinner, and would disdain as much as a lord to do or say aught to conciliate one, is the healthy attitude of human nature. A boy is in the parlor what the pit is in the playhouse; independent, irresponsible, looking out from his corner on such people and facts as pass by, he tries and sentences them on their merits, in the swift, summary way of boys, as good, bad, interesting, silly, eloquent, troublesome. He cumbers himself never about consequences, about interests: he gives an independent, genuine verdict." *

In these latter cases, in that of the boy for whom an education is bought in entire ignorance of its meaning and value, and in that of the boy for whom the purchased culture has its full and acknowledged social worth, there may be more and better result than in that of the young man educated wilfully and perforce. Provided there are not purchased for them, together with their college courses, ineradicable idleness and dissipation, these young men cannot avoid gaining, unconsciously to themselves, much that is of the greatest permanent value, many things having wide influence upon them and upon those about them, to the end of life, but for which the university gets no credit, of which there is no mention in the scheme of instruction, and the existence of which is not, even tacitly, implied in their more or less comprehensive diplomas. And these things they acquire, — useful and valuable things, I mean, — because they are receptive, because they acquiesce in the course laid out for them, and because they have some sort of dim idea of the necessity for susceptibility and growth. The coerced boy will, it seems to me, fail even of these benefits. His continued revolt will leave him open to no influence except to that of evil, which needs no

* Emerson, Essays, First Series, "Self-Reliance."

invitation, but obtrudes itself into every mental and moral vacuum, and stands ready, as we are told, to every idle hand.

What is there, then, in the atmosphere of the university, that permeates even the mind not prepared for or even conscious of it? If it is wished to make a scholar, a teacher, a professional man, or an engineer of a boy, and if it is desirable and possible to give him the best training for the life work chosen, he is sent, as a matter of course, to the best college, professional school, or scientific school available. But the demand for these specialties is limited; the boys who have decided inclinations in the direction of them are few and far between. The great mass of young men for whom higher education is possible are destined for pursuits to which no university can, directly, train them; for occupations whose details can be mastered only by actual experience therein. Why should these boys be delayed four, or even more, years in beginning their life's schooling, by a university career? If a man puts one of his sons into business at sixteen, and another into college at eighteen years of age, will not the latter be, not only six years behind the former in starting out in life, but always six years behind? From a practical point of view, will not the latter have lost six years of his life, six of the most ambitious and acquisitive years, to no purpose? Distinctly, no! Provided the college-bred boy is of average intelligence, provided he is not averse to a university training, and provided his parents and his teachers have done their duty in preparing him — body, mind, and soul — for meeting that which must, sooner or later, be met everywhere, but for which the unforewarned student is perhaps a peculiarly easy prey, — the temptations and pitfalls of life, — he will soon far outstrip his uncultivated brother. At the completion of his studies he will be much behind this brother. He may not know how to calculate percentage readily, and may fail to distinguish between a government bond and a worthless share of stock. But in latent breadth of understanding, in mental grasp, in tact, and, if he has been properly taught, in common sense, he far outranks the other. He may, furthermore, know Greek, or he may be able to differentiate functions, or he may not be dumfounded, as is his brother, by reference to many subjects, intellectual and scientific; but all this counts for very little, as such. It is not the ability to read Homer that is of value, in itself, except to the student of Greek; it is not the knowledge necessary to calculate the strains in a roof truss that counts, of itself, except to the architect and civil engineer. It is the breadth of mind betokened by the acquaintance with these things; the logical power and the reasoning facility, which can and will be exerted as readily upon the questions of everyday life as upon these

special problems; and, above all, it is the manliness instilled into every right-minded young man by the training of his higher faculties, which elevate him above his less-favored brother.

A university course shows a boy, or should show him, that there are higher things in the world than he has reached, or can ever hope to attain; it opens to him a vista of infinite possibilities, leading to better results than money-getting or political scheming; it teaches a boy self-respect, and it should teach him self-reliance. It should, too, if it be rightly carried on, fill him with the hope of and aspiration for further acquisition, mental grasping that shall be as eager at seventy as at twenty years, that shall not give up hard problems, but shall find ever greater delight, with greater maturity, in attempting their solution. University work is like the climbing of a mountain, easy or difficult as we are trained or untrained, and as we judiciously or injudiciously perform it, and opening to us, at the summit, an horizon unimagined and impossible of comprehension to those dwelling at the base, and unwilling or unable to earn the seeing of it.

Though a college graduate were to never read another word of Latin, French, or German; though the systems of political economy become hopelessly entangled in his mind; though the theories of light and heat fade from him; he has gained, nevertheless, something, nay much, that cannot be taken away. His mental horizon has been widened, and it can never again be contracted for him. He has possessed himself of a breeding, a polish, — call it what you will, — that it is impossible to wholly lose, neglect and abuse it as he may. Though he may fall wofully short of his early promise, though his subsequent life may be such as to prove the uselessness of any effort on his account, nevertheless, while there is promise, while the unknown is still before the boy, he ought, if he be not too dull, too vicious, too utterly in opposition to his best interests, he ought to have the opportunity given him, if possible, to enlarge his life, to increase what capacity there may be in him for good, by letting him come into relations with a higher life, with a more active intellectuality, with a body of men engaged in the pursuit of broader aims, than it is possible to find for a boy outside the walls of the university.

Of course, unless a boy have extraordinary mental endowment, he will secure only a small percentage of the benefit possible to be obtained from a college course. To gain the utmost, in one sense, from the curriculum of any reputable university, a man should not enter it before his fortieth year. On the other hand, however, in point of plasticity, of eagerness, of rapid acquisitiveness, the boy is far ahead of his

maturer self. There is, necessarily, enormous waste; the time when a human being shall acquire to his fullest capacity is as distant as is that when it shall be possible to utilize every atom of power from the burning of a ton of coal. Nature is prodigal in everything. Too much must not be expected from the four years' residence in the university. It is, after all, but one of the first steps, though a vastly important one, in the boy's life. If it is felt that the newly made bachelor of arts or of science has learned only a little of the little that it is possible for the university to teach; if the opportunities wasted, and the chances for improvement lost, are seen too vividly, it is well to remember that life is largely made up of unseized or half-seized chances, and to be thankful if a young man does his duty to the best of the ability and knowledge given him at his time of life. If a man, as he grows older, learns, every day, how much of good he passed by in his college life, he finds out, on the other hand, more and more, how much he unconsciously imbibed, how many things he owes to the college that, at the time, were unheeded or thought of no account. The points of view of life, at its different stages, are so diverse as to appear almost antagonistic.

I have said that a rightly conducted university course fosters self-reliance and self-respect. To this the opponent of the college will doubtless agree, adding, however, that these qualities are encouraged and inflated beyond all reason and propriety. He will, probably, maintain that, if the university is to be continued at all, the old paternal system of government should be restored. He will aver that in treating boys as men, thereby to develop the latent manliness within them, they are thrown upon resources which do not exist, they are set adrift, rudderless, to wander and founder as they may, and that, in this attempted fostering of self-reliance, their self-respect is puffed up into ignorant pride and obstinacy. Where this unhappy result is seen, it is rarely the fault of a system depending upon the essential manliness of boys. The home training is to blame; the neglect of the father and mother to discipline and practise the child, from the very cradle, in obedience, self-control and reasonableness, is to be held responsible. A boy of eighteen, if he has any good in him at all, will be less liable to stray from the right, if he is put upon his honor as a man, than if he is conscious of being always spied upon by the eye of authority. Under such conditions, he shifts the responsibility for his misdemeanors upon the power that failed to watch closely enough. He feels, in a measure, exonerated from blame, since he may share it with his guardians. A man's conscience, and a boy's conscience no less, is the only watchman who never sleeps; he needs only to have been taught his duty.

As for the overweening quality of a collegian's self-respect, through which it becomes self-conceit, this is a failing incident more to the time of life than to the nature of the university training. The very fact of its abnormal rise during the collegiate period will make its subsequent, inevitable fall all the greater, and, therefore, all the more salutary. And a college conceit has little of the Pharisee about it. It is rather collective than individual. A university graduate is not so much proud of his own achievements, and assured of his own infallibility, as he is conscious and confident of the worth of his college and his class. Straightforward, unconventional intercourse with other boys and other men is antagonistic to the species of conceit that clings to a man through life. It is only the recluse, the solitary, who gives thanks for his own superiority. A college man, after running the gauntlet of the frank criticism of his peers, after learning all his own peculiarities and shortcomings from lips that hesitate at nothing through fear of giving offence, such a man cannot have much individual conceit. He has been thrown among too many intellectual lights to have a very exalted idea of his own brilliancy. He may put on a bold front, but, inwardly, he quakes before the cold eye of the world. He only half believes in himself, but instinct urges him to feign full assurance; for, if he has not faith in himself, the world is too crowded and too busy to be his surety.

The average collegian is then, I might almost say, a child in practical experience. He is far behind, for the time being, in the race for money, for place, for position. He has, in greater or less quantity, a store of information, represented by equivalent marks, prizes, and what not, which he thinks will be of direct and immediate use to him, but of whose value the world is somewhat sceptical. He has, moreover, unknown to himself and cloaked, it may be, by passing self-opinion, a larger store of more precious things; of breadth, of catholicity, of tolerance, of desire for acquisition, of belief in something higher and better than, but not inconsistent with, wholly practical things. He has acquired a respect for himself, founded upon a belief in the possibilities of man in general and of this man in particular. And, although he may endeavor to impress others with a sense of his greatness, he has an inward conviction of insignificance and a hope of growth. Above all, through contact with great minds and great laws, he has had developed in him a feeling of reverence, the awe which is the basis of all truly religious feeling. The atmosphere of learning, the wonderfulness of all that is revealed to him, heedless though he be of it, is far more likely to arouse, in a boy of eighteen, the attitude of worship, of conviction that there

must be greater behind the great, than is a too early knowledge of a world full of meanness, of subterfuge, of low aims and petty criminality. The highest worship, the purest spirit of belief, is from the fullest and most evenly balanced intellect. The few only can be great scholars; the many may be schooled. The few only can arrive at the sublime heights of intellectual power; the many may and should journey towards them, and, in so doing, find infinite reward for every sacrifice.

THE REMOVAL OF ROOF WATER FROM BUILDINGS.

BY DWIGHT PORTER, PH.B.

IN most cases roof water will soon take itself off without assistance, but its manner of doing this, and the final disposal thus made of the water, are not always satisfactory. Dripping eaves projecting over city sidewalks would be an intolerable nuisance; and whether in city or in country, rain water allowed to fall freely from the roof to the ground next the building tends to dampen the cellar, foundations, and walls, and thereby to injure the health of inmates of the building, as well as to harm the structure itself and property contained within. It therefore becomes essential to direct the course of water falling upon the roof, and to convey it away to a proper point of discharge. To effect these purposes various arrangements have been employed, some of which will be mentioned.

For directing the course of the water, as it is received upon the roof, to a suitable point of discharge, we have gutters. On old-fashioned country houses these were often made from a log of moderate diameter, sawed lengthwise, gouged out, and supported by hooks or brackets under the eaves. In modern construction the gutter is very commonly made angular in cross-section, formed upon a wooden cornice, with a protecting sheathing of tin, galvanized iron, or copper. Half-round or angular gutters of these metals are also used hung at the eaves.

Galvanized Iron Gutters

Leaders, conductors, or rain spouts, as they are variously termed, receive the discharge from the gutters, and, descending toward the ground, convey the water a stage farther in its journey. The problems connected with rain leaders are not very intricate, but yet they have not always been well solved. It is not a difficult matter to arrange a few leaders for receiving the roof water of a building; but from mistaken economy, or from lack of knowledge, or of forethought in the matter, they often prove inefficient when most needed, and are a constant source of trouble and expense.

Their size, which is commonly determined by experience and judgment, and not by calculation, ranges in diameter from 2 to 6 inches. Two-inch pipes are too small to serve to advantage as main leaders on almost any building, being easily choked. Three-inch and 4-inch pipes are suitable and common sizes for ordinary dwellings and small commercial buildings. The 5-inch and 6-inch sizes find employment on large structures.

The Produce Exchange building, in New York City, with a roof area of three-quarters of an acre, roughly speaking, has twelve leaders, of about 5 inches diameter. The roof, which is paved with fire-bricks, is graded with slopes of perhaps 1 in 50 toward the points at which the leader openings are placed, most of these draining surfaces of about 40 x 70 feet each. The provision here made is equivalent to about 1 square inch of leader opening to 140 square feet of roof surface. On the Sloane building, at Nineteenth Street and Broadway, with a roof area of 18,000 or 20,000 square feet, sloping 1 in 25, there are two leaders of about 6 inches diameter, and a third rectangular, 4 inches by 6 inches. This gives an allowance of 240 square feet of surface to the square inch of leader opening, while on the Massachusetts Hospital Life Insurance Co.'s building and the Hemenway building, in this city, the proportion is only from 60 to 70 square feet to the square inch of opening.

	Approximate Roof Surface.	Approximate Surface per sq. in. of Leader Opening.	
Produce Exchange Building, New York,	33,000 sq. ft.	140 sq. ft.	Twelve 5″ leaders.
Sloane Building, New York	19,000 "	240 "	Two 6″ leaders, and one 4″ × 6″.
Mass. Hospital Ins. Co. Building, Boston,	6,000 "	70 "	Seven 4″ leaders.
Hemenway Building, Boston	4,000 "	60 "	Five 4″ leaders.

Whether a roof slope steeply or gently, there is a certain amount of water falling per second or per minute in storms, which must be removed; but I have learned of no generally recognized rule among architects as to the leader provision which should be made for it.

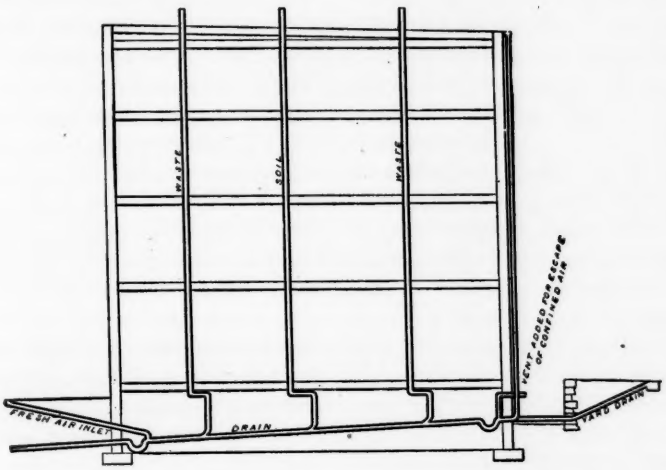
A vertical rain leader does not, of course, run full bore, even in the hardest storms, and yet, if carried down from the roof with its course unbroken by sharp bends, and if given a suitable opening at the top, there is probably little danger of its proving inadequate. It is very common, however, to introduce abrupt changes of direction to suit peculiarities of architecture, by which the carrying capacity of the pipe is cur-

tailed, and the liability of choking by leaves, rubbish and ice is greatly increased. On a business block on Sudbury Street, in this city, may be seen a rain leader which within a few feet of the point of leaving the gutter makes four abrupt and nearly right-angled changes of direction. It will frequently be noticed on buildings, also, that the immediate connection between the gutter and a 4-inch leader of ample capacity is effected by a very much smaller pipe of lead.

In connection with important buildings there is perhaps more need of caution in designing the drain of suitable size than in fixing upon the size of leaders. Formerly house drains were made entirely too large, an error which has come to be recognized, and has led to the practice of using comparatively small sizes. These are advantageous for procuring an effective scour of the pipes by the slight flow of ordinary house drainage, but have in numerous instances proved practically insufficient for managing the volume of water furnished by heavy storms, which is doubtless often hundreds of times as great as that coming from interior house drainage. In the Sloane building, to which reference has already been made, I am informed that it was found necessary, on this account, to enlarge the main drain from 8 inches diameter to 10 inches, considerable damage having been suffered, two or three summers ago, from a flood of rain water during a severe storm.

A practical difficulty connected with the delivery of roof water to the house drain has also been experienced under certain circumstances, in the apparent carrying along by friction, and imprisonment, of a large amount of air by the descending column of water, and a consequent pressure upon the traps of connecting pipes, and even a serious interference with the flow in the main drain itself, unless relieved by ample venting. An instance was mentioned to the writer by Mr. John C. Collins, Chief Inspector of Plumbing for the New York Board of Health, in which very considerable injury to property resulted in this way, the rain water bursting out near the bottom of a leader and flooding the basement of a building. The leader ran down the rear of the building, the main part of galvanized iron, succeeded near the bottom by a cast-iron shoe connecting with the drain. In the drain was a running trap near the foot of the leader, and another near the front of the building. Two stacks of waste pipe and a stack of soil pipe joined the drain between the traps, and there was near the front of the building the usual 4-inch fresh-air inlet. Still, the 5-inch drain appeared incapable of serving the leader in heavy rains, and water would back up 10 or 12 feet high in the leader and overflow at the top of the cast-iron shoe. That the trouble was due to the interference of imprisoned air

was indicated by the fact that it was partly relieved by inserting a 2-inch air-vent between the leader and the first trap, and entirely overcome by a 3-inch vent.



Now and then we find the roof water carried to the street sewer in an independent line of pipe, but the usual, and what is generally considered the preferable practice, is to conduct it directly into the house drain, sometimes at the back end, sometimes at the front, just inside the main trap, and again at both these or at intermediate points, according to circumstances.

On a large proportion of city buildings the rain leaders run down the outside of the walls, but yet in a considerable number they are carried down within the walls, in which case it is evidently desirable that the same care should be taken to prevent the escape of drain or sewer air through defective material and joints that would be taken with stacks of soil or waste pipe. Consequently we find in the public regulations in force in large cities requirements that the leaders shall be constructed of iron (in New York copper may also be used), if carried within the walls. In New York City it is permitted that leaders of iron or copper shall be without traps, unless the top is near a window, in which case a trap is required at the base. In Boston, however, all leaders must be trapped in new construction.

The troubles encountered in the practical service of leaders and gutters are occasioned in part by their becoming choked with leaves or rub-

bish, but principally by their being clogged and burst by accumulations of ice in winter. Leaves and rubbish may be largely excluded from leaders by the use of wire strainers or iron gratings, though these of course do not prevent accumulations outside and near the tops of the leaders. In the midst of a large city, however, leaves are usually strangers, and in a cold climate the trouble with gutters and leaders comes from ice. It is very common to see a tin or a galvanized iron leader brought from the roof down the face of a building and terminating in an iron "pipe-shoe," as it is called. Such an arrangement will be found on the brick blocks of tenement houses on Nashua and Billerica streets, for example, in this city, and walking through these streets it will be noticed that nearly every one of the cast-iron shoes has been split by ice. Leaders often become encased in ice to the size of a barrel, from top to bottom, while from gutters and eaves depend huge icicles which threaten the heads of passers below.

These troubles from ice cannot in all cases be conveniently and entirely avoided, but on important buildings it is perfectly practicable to escape them by proper location of leaders and gutters, by the use of pipes of suitable material and shape, and by the supplementary employment, in some cases, of steam.

On steeply pitched roofs, gutters are naturally found at the eaves, either built out or suspended, as has before been mentioned, with leaders running down on the face of the walls. But large business blocks are now very commonly built with tolerably flat roofs, a long slope from front to rear being succeeded by a short rise to the edge of the roof, the V-shaped channel between the two slopes serving as an ample gutter. Sometimes, indeed, as on the Morse and the Wilde Estate buildings, on Washington Street, in this city, the roof is given a slope from both front and rear toward the centre, where the gutter channel is thus formed. In either of these constructions, the gutter being entirely upon the main part of the roof, it is natural and easy to carry down the leader within the building, and where this is done, little or no difficulty is experienced from ice. Rain, snow, and ice then take care of themselves, and the heat of the building, supposing it to be occupied, is found sufficient in this climate to prevent accumulations within the leader.

As has already been said, the regulations in large cities would prescribe for such cases iron or copper pipes, which indeed would naturally be employed. The same materials may be, and often are, utilized also for outside leaders, but galvanized iron and tin are far more common. The choice of material is important chiefly in connection with the lasting qualities of the pipe: the shape of the cross-section, and the mode

of making the longitudinal seam, are important as regards protection against bursting by ice.

In some parts of the country zinc was once almost exclusively employed for leaders; in other parts, tin. Tin pipes are still perhaps the most commonly used, on the whole, of all kinds, on account of cheapness in first cost; but galvanized iron pipes are considered superior, and being not greatly more expensive than tin are given the preference in good work. Either material, however, is subject to gradual corrosion from the water which comes in contact with it, more rapid corrosion from the moist salt air along the coast, and still more rapid corrosion from steam and from sewer air. In New York City, for instance, there are many leaders having untrapped connection with drain or sewer, and these leaders, whether of tin or of galvanized iron, are said to withstand corrosion generally but a very few years.

There are two principal varieties of tin in use for roofing and leader purposes. The old-fashioned or bright tin is "black iron," as it is called, or more and more commonly at the present time a mild steel, covered with a coating of pure tin. The dull tin, which is now largely made, has the coating of tin with an admixture of lead. The bright tin, which alone of these varieties is safe for culinary articles, and which is often also supposed to be best suited to use on buildings, is considered by many whose experience is of value to be inferior for this purpose to a good dull or "leaded" tin. The latter material, when re-dipped in the process of coating, resists corrosion from moist and especially from salt air much better than the former.

The so-called galvanized iron is either black sheet iron covered directly with a coating consisting chiefly of zinc, or it is sheet tin so covered, the iron having in this case a double coating.

Far superior to either tin or galvanized iron is copper, which is practically unaffected by the ordinary agents producing corrosion of roof coverings and leaders. It has been very considerably employed in first-class work, but its cost is at present a serious bar to extensive use. Galvanized iron leaders cost perhaps 20 per cent more than tin leaders of the same size. Two or three years ago, before the rise in copper, leaders of the latter material cost approximately half as much again as those of galvanized iron, but I am informed that they now (September, 1888) cost about two and one-third times as much as the galvanized iron.

Copper leaders are made of all shapes and sizes used for other materials. Hot-rolled copper was the variety formerly employed on buildings, but prejudice was aroused against it because of its softness and

the ease with which it loses its shape. Cold-rolled copper, which is now utilized in good work, is harder and stiffer, and if selected of a grade weighing 18 or 20 ounces per square foot, is found to be a superior and satisfactory material. Copper expands and contracts under changes of temperature much more than iron, and allowance often has to be made for this when the metal is used in construction. In a long vertical rain leader of copper provision for change of length is often made by introducing one or more slip joints, at which there is a lap of perhaps three inches, and at which solder is omitted. The slip joint of course offers some opportunity for the escape of sewer air, if that is allowed to enter the leader; but if well made, the joint is claimed to be soon rendered fairly tight by a slight coating which forms on the metal. The protection afforded to tin and galvanized iron pipes by their distinctive coatings may be further increased by coating with tar and asphalt, or by use of the adamanta or other coverings.

But while a suitable material is essential to the endurance of the pipe against corrosion, its protection against bursting by ice is to be obtained partly by the mode of joining the material, but chiefly by the shape given the pipe in cross-section. The common tin pipe is made in short lengths soldered together at the transverse joints, each length having a straight longitudinal seam, which is either a soldered lap joint or a simple locked joint. The lap joint is not so strong as the rest of the pipe, and under the great expansive pressure of ice is opened. Whatever, then, tends to strengthen the longitudinal jointing of the pipe gives greater resistance against moderate ice pressure, although no plain pipe of ordinary thickness is proof against rupture by ice. The locked joint is an improvement upon the plain soldered lap joint, and is used for galvanized iron and copper as well as for tin. The plain lap joint can be strengthened by riveting, and I have seen copper leaders made with a straight soldered and riveted seam which is claimed to be stronger than the main body of the pipe, the latter yielding first to ice. Galvanized iron leaders are also made with a patented spiral and riveted seam, which renders them very strong.

Economy of material for a given cross-section of pipe demands the use of a plain circular form; but it is evident that no shape would be more unyielding against the expansive power of ice, and in order to accommodate the latter and prevent rupture, the expedient of a fluted or corrugated pipe was hit upon some fifteen or twenty years ago, and patented. This form of pipe has been very extensively used, and appears to have been generally satisfactory in resisting ice, readily changing its shape under pressure. Tin, galvanized iron, and copper

pipes are all to be had of the corrugated form, being usually circular in general shape, but often made rectangular as being more ornamental. A good corrugated copper pipe would appear, all things considered, to be the best available construction. The patent upon corrugated pipes expired a year or two since, and they are now manufactured by a number of competing firms.

Even if a leader pipe be used which will not be ruptured, it is, if exposed, liable to become so choked with ice as to be unable to carry off water, and the same thing also happens in the case of gutters. Hence in a climate as cold as that of Boston resort is frequently had to the use of steam, not so much, however, for the purpose of preventing the formation of ice in freezing weather, as to clear a passage for the water when a thaw comes on. Most large buildings at the present time have a supply of steam, either for heating or for power, which can without much difficulty be drawn upon during the daytime for use in the way that has been mentioned.

The most common method of using steam for thawing out leaders is to introduce a small jet from perhaps a $\frac{3}{8}$-inch or a $\frac{1}{2}$-inch pipe at the base, and allow the steam to rise up through the leader. This plan is followed at the Wakefield building, on Canal Street, in this city; and as a precaution steam is thus at times introduced also into the base of an iron leader in the Wilde Estate building. At the Sloane building in New York, the same plan has been successfully tried, but has been practically superseded by allowing hot water to drip into the tops of the leaders. Waste steam from the heating and elevator systems passes into small drum-shaped condensers on the roof, and the hot water of condensation is conducted through drip-pipes to the leaders. The climate of New York City is so much milder than that of Boston that comparatively little trouble from ice is experienced; and the common practice of an untrapped connection with drains and sewers, the air of which is warm, tends to prevent serious accumulations within the leaders.

Another method which is sometimes, but less commonly used, is to carry up a steam pipe through the interior of the leader. At the Cheney building, in Hartford, Conn., a $\frac{3}{4}$-inch steam pipe is thus employed. This pipe has an iron cap a foot or so above the roof, the cap being perforated by a small hole to permit some circulation of steam, but the hole quickly becomes stopped by rust. The condensation of steam within the pipe, and the freezing of the water thus formed, has split the pipe at various points; but the steam escapes all the more readily in consequence, and the arrangement is entirely successful in clearing out the leaders.

Even if the leaders are kept open, the gutters are very likely to

become clogged with ice, and then fail to perform their duty. Attempts have therefore been made to clear these also by the aid of steam, and on the Studio and Museum buildings in this city may be seen arrangements of steam pipes for this purpose. The gutters are of the common half-round metallic type, projecting out from the edge of the roof, the steam pipes extending along over the centre of the gutters and about on a level with the top. On the Studio building the pipes are pierced beneath with small holes at intervals of, say, six inches, with the object of directing downward into the ice of the gutter a great many small jets of steam. This device is not satisfactory, however. A hole is melted in the ice by each jet, but ridges are left between the adjacent holes, that have to be chopped away. Water also enters from the gutter into the steam pipe, freezes there, and bursts the pipe.

It seems probable that if steam pipes are to be used in gutters, they should either be arranged with jets closer together than in the case just mentioned, and perhaps directed obliquely into the gutter; or they should be tight pipes laid on the bottom of the gutters, with a circulation of steam assured by an opening at the end or by a properly arranged return pipe, and with sufficient grade so that the water of condensation may readily flow off.

On the Wakefield building, and to some extent on the Studio building, steam is brought on to the roof from the nearest convenient point in a hose, and in that way directed at will upon the ice in the gutters. In the latter building the steam employed is that used for heating, is at a pressure of 6 or 8 pounds only, and is found not very efficient in cutting out the ice; but on the Wakefield building the steam is that used for power, is delivered under a pressure of 50 or 75 pounds, and is considered very satisfactory in clearing the gutters.

In conclusion, it may be said that in the case of large buildings, at least, it is possible, by some of the methods that have been pointed out, to avoid all inconvenience from roof water, from whatever source; and on private dwellings, if the water is brought down from the roof in a vertical and unbroken descent, and a good corrugated pipe is used, there will be but little trouble.

In most cities, the destination of the water, whether it be directly discharged into the house drain or into the street gutter, must quickly be the public sewers. To what extent, if at all, this water shall be excluded from the sewers which convey the other house-drainage, is a question of importance in certain cities, but its discussion need not be entered upon here.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
September, 1888.

A GLASS OF WATER.

By A. L. KEAN and E. O. JORDAN.

When one drinks a glass of ordinary city water, he often drinks not only H_2O, but also a multitude of living organisms. These are interesting from a purely scientific point of view, and have also much practical sanitary significance. Now that it has been found that a number of acute infectious diseases, such as typhoid fever, cholera, etc., are caused by certain tiny plants called bacteria, we can appreciate more fully than ever the dangers of an impure water supply. If, for example, the germs of typhoid fever find their way in any numbers into the water supply of a great city, it is not pleasant to contemplate the possible result. There is little doubt, however, that the danger is sometimes overestimated. When the new methods for the biological examination of water first came into use, it was thought that water containing any considerable number of bacteria was unfit for drinking purposes. As we gradually came into a more intimate knowledge of the subject, however, it was seen that there are many forms of harmless "water-bacteria" capable of growing and multiplying even in distilled water. These innocent and probably useful forms may be present in water in comparatively large numbers without serious damage to health. Yet for the sake of putting some sort of limit to the number of bacteria a good drinking-water should contain, it is generally considered that any water that contains more than fifty to one hundred bacteria in a cubic centimetre should not be used unless purified in some such way as by boiling or filtering. This number, at the best, is an arbitrary standard, and in some good drinking-waters is frequently exceeded. The limit given is based on general ideas of safety rather than on any accurate and precise knowledge.

The present examination of Cochituate water was carried on along two separate lines — one, the usual bacteriological examination, and the other a microscopical examination of the algæ, etc., by a new method lately devised by one of us.*

The samples of water were taken in an ordinary glass holding a little over 200 cubic centimetres. The glass was carefully cleansed, and before each sampling was rinsed three times with the tap water. It was

* Cf. Science for February 15, 1889.

then filled to the top of the 200-cc. mark, and the bacteriological sample consisting of one cubic centimetre removed and planted. In every case the sample was planted within five minutes from the time of collection, in order to preclude all possibility of increase by standing. The remainder of the water was used for the microscopical examination.

The method used in making the microscopical examination was as follows: The glass of water, from which the bacteriological sample had previously been taken, was poured into a funnel, in the end of which was a half-inch of fine sand, held in place by a plug of wire gauze: thus allowing the water free passage while holding the sand in place. Through this sand the water quickly filters, the microscopic organisms being detained by the sand. The bacteria, however, pass through with the water. The plug of wire gauze is then removed, and the sand washed down into a watch-glass with one cubic centimetre of the filtered water directed from a pipette. The heavy sand sinks to the bottom of the watch-glass, all the grains falling apart and setting free the light micro-organisms which remain suspended in the water. By this process all the organisms contained in the glass of water are collected into the one cubic centimetre in the watch-glass. The object of this is to make the water so charged with organisms that it can be examined under the microscope; for, since only a very small quantity of water can ever be examined at once, it is rarely practicable to subject waters of comparative purity to a direct examination, because a number of examinations might be made without finding anything at all. The wash water containing the organisms is then examined under the microscope. The unit of bulk used is a cubic millimetre, and a sample of the water is placed in a chamber of that capacity. All the organisms in this chamber are counted, and by multiplying the count by 1000, the approximate total number contained in the glass of water is obtained. The numbers obtained at first sight seem enormous; but when the minute size of the organisms is considered, it is easily seen that they must form a very small per cent of the bulk of the water in which they are contained. It is, of course, very necessary to make several control counts and to strike the average of the different samples.

So far as is known, the common forms of algæ are in themselves perfectly harmless; but, unfortunately, wherever they live there also they die. Their bodies thus supplied to the bacteria enable these latter to thrive and multiply, and if a few harmful bacteria happen to be present in the water, they are given the chance to increase their numbers to what may be a dangerous extent. The inter-relations existing between the bacteria and the other microscopic organisms are at

present very obscure. From the figures obtained from the samples, it is impossible to deduce any definite relation between them.

It must not be supposed for an instant that all the forms figured were found in a single glass of Cochituate water, or, on the other hand, that they represent all the species ever found in that water. They are simply figures of the different species actually observed in the ten samples taken. Of those figured, *Asterionella* (5) and *Melosira* (15) are the most common; after these come *Chlorococcus* (8) and *Tabellaria* (16). The others appeared only occasionally, though it would be unfair to say that they are uncommon, since they are all known to occur frequently in drinking-water.

The method employed in the bacteriological examination was the method of gelatin plate culture devised by Koch in 1881. One cubic centimetre of the water is thoroughly mixed with a larger amount of melted nutrient gelatin, and the whole poured out on a glass plate. Each living germ that is originally present in the water forms a little group or colony about itself in the stiffened gelatin, and in the course of two or three days these colonies are counted and examined. All pipettes, plates, and other apparatus used are carefully sterilized by heating to 165°–195° C. for an hour. The gelatin is sterilized by heating in a steam bath for twenty minutes at a time on several successive days.

The number of different species found in a sample varied from four to nine. The species were mainly common kinds, the very common "green water-bacillus" greatly outnumbering any other kind in every sample examined. Other species found in several samples were (1) the *Proteus* of Hauser, which is frequently found in water and is generally present in putrefying matter everywhere; (2) a short, plump, oval bacillus, probably not yet described, which liquefies gelatin rapidly and produces a very fine yellowish white growth on potato; (3) a bacillus that liquefies gelatin and sends out small migrating colonies which give a peculiar "spatter" appearance to the plate. These and the green water-bacillus are all probably perfectly harmless, at least in small quantities. When, however, we take into our bodies even these comparatively innocent forms in so large numbers as indicated by the sample of Jan. 18, — 550,000 in a glass of water, — it really becomes a question whether or not these apparently harmless bacteria may not be responsible for an occasional "cold" or other slight ailment. Force of numbers may accomplish what a few thousand bacteria could not effect. This is something, however, about which nothing definite is actually known. The average sample of Cochituate water for the month of January, 1889, is certainly nothing to be alarmed at.

Date.	Hour.	Algæ in 1 cc.	Bacteria in 1 cc.	Mean Daily Temperature.	Rainfall.
Jan. 15	12.30 P.M.	50	63	27.5	0.00
" 17	" "	100	69	54.5	0.35
" 18	" "	315	2793	37	0.00
" 19	5.30 "	305	1134	—	—
" 21	12.30 "	270	114	34	0.38
" 22	1.45 "	200	78	23.5	0.00
" 23	1.00 "	315	65	28	0.00
" 24	3.00 "	175	73	40.5	Tr.
" 25	12.45 "	585	68	37	Tr.
" 26	2.16 "	130	82	—	—

Average in 1 cc, 245 algæ, 454 bacteria.
Average in 200 cc, 49,000 algæ, 90,800 bacteria.

If we throw out the unusually high numbers of bacteria found on the 18th and 19th, the average is 80, instead of 454. The high numbers for those dates are probably due to the heavy rain-storm and high temperature of the 17th, but for the present this is merely a conjecture.

A glass of Cochituate water, then, from a Boylston Street tap, from Jan. 15 to Jan. 26, 1889, contained on an average 49,000 algæ and 90,800 bacteria.

FIGURES.

1, 2, 3, 4. *Bacteria.*

5. *Asterionella.* *A*, front view; *B*, side view; *C*, a colony.
Color, greenish yellow, with numerous vacuoles.

6. *Cyclotella.* *A*, front view; *B*, side view.
Color, greenish yellow; the diatomin which gives the color is contained in numerous round globules.

7. *Synedra.* *A*, front view; *B*, side view.
Color, greenish yellow; the color being confined to the edges.

8. *Chlorococcus.*
Color, dull green, varying to a brilliant green.

9. *Calothrix.*
Color, pale green, with numerous very prominent black dots.

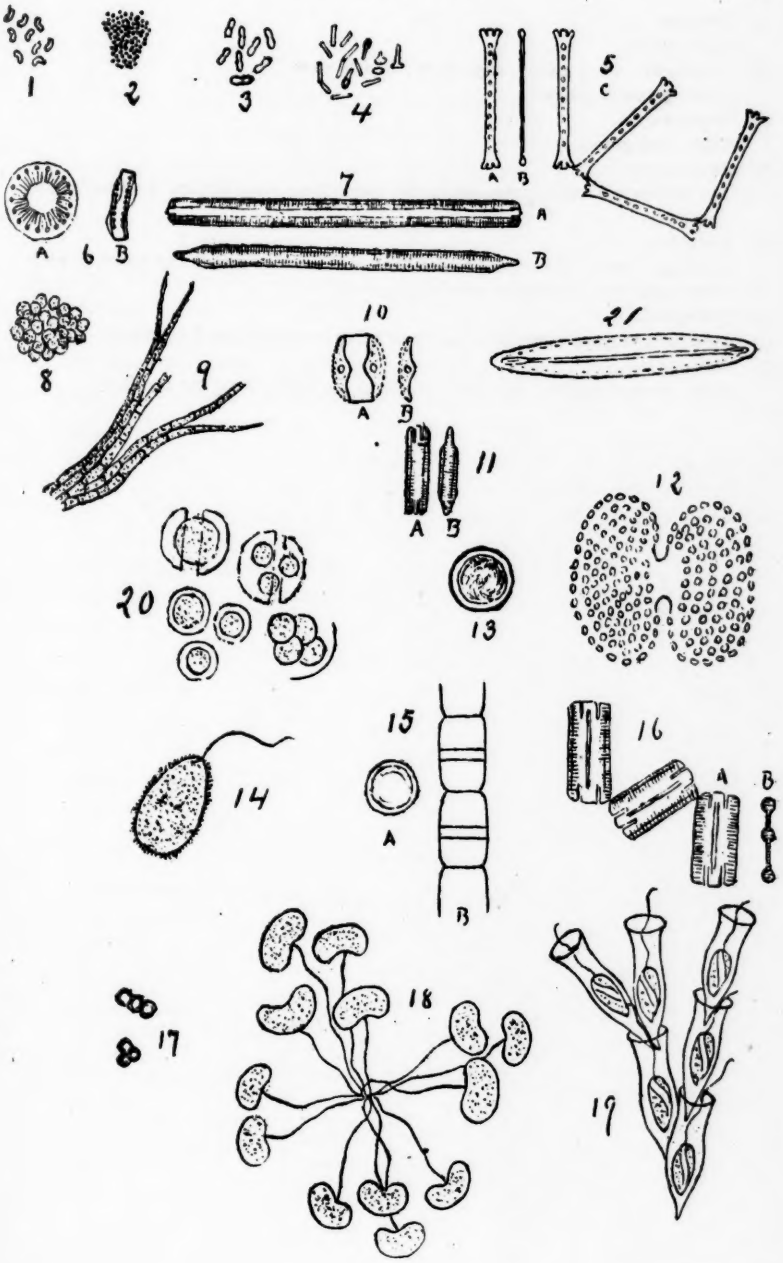
10. *Amphora.* *A*, front view; *B*, side view.
Color, greenish yellow, much darkened along the edges by the external markings.

11. *Fragillaria.* *A*, front view; *B*, side view.
Color, greenish yellow, evenly distributed.

12. *Closterium.*
Colorless.

13. *Trachelomonas.*
Color, dark brown.

14. *Chaetoglena.*
Color, transparent green.


1
2
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4
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A
B
C
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15. *Melosira.*
Color, green.
16. *Tabellaria.* *A*, a colony, front view; *B*, side view.
Color, greenish yellow.
17. *Anabæna.*
Color, blue-green.
18. *Pleurococcus.*
The bodies are clear green, while the connecting filaments are transparent and colorless.
19. *Dinobryon.*
The cups in which the organisms are contained are transparent and colorless, while the organisms themselves are a bright green.
20. *Protococcus.*
Color, bright green; the containing wall being transparent and colorless.
21. *Pleurococcus.*
Color, greenish yellow, contained entirely in the centre along the mid-line.

AN ACCOUNT OF CERTAIN EXPERIMENTS UPON SEVERAL METHODS OF COUNTERBALANCING THE ACTION OF THE RECIPROCATING PARTS OF A LOCOMOTIVE.

By GAETANO LANZA, S.B., C. and M.E.

With Edward H. Dewson, George F. Reynolds, and Edward M. Smith.

The object of this paper is to give an account of the experimental work that has been done in the Laboratory of Mechanical Engineering of the Massachusetts Institute of Technology in regard to the effect of different methods in use for counterbalancing the throw of the reciprocating parts of a locomotive; and also as to how to counterbalance the horizontal throw and prevent nosing.

These experiments have formed the subject of the graduating theses of the following three students, viz.: Edward H. Dewson, '85; George F. Reynolds, '86; and Edward M. Smith, '88. They made use of a model of an eight-wheel Hinkley Passenger Locomotive, one-eighth scale, which was suspended by four wires, one at each corner, and set in motion by steam. The following are some of the dimensions of the locomotive:—

Total wheel base	22′ 5¼″
Rigid wheel base	8′ 6″
Length of stroke	24″
Diameter of cylinder	17″
Diameter of boiler	52¼″
Length of tubes	11′ 0″
Diameter of drivers	5′ 3″
Diameter of truck wheels	30″
Distance of middle of cylinder from main drivers	11′ 1½″
Weight on drivers	50,000 lbs.
Weight on truck	30,000 "
Total weight	80,000 "
Piston, complete with rod	285 "
Cross-head with key	134 "
Main rod (entire)	305 "
Main rod, back end	196 "
Parallel rod	297 "
Main pin (before pressing in wheel)	68 "
Back pin (" " ")	86 "
Crank pin boss (estimated)	71 "
Driving wheel (rough)	1905 "
Tire	1330 "
Boxes	227 "

The latter includes box, sponge box, saddle, and brass. Ten per cent of the last three weights should be deducted for finish, which will give

Weight of finished wheel	2895 lbs.

From the weights of the locomotive on the drivers and truck, the centre of gravity of the entire machine is found to lie 9′ 7¼″ back of the centre of the truck, and 1′ 6¼″ forward of the centre of the main driving axle.

From these and other data an eighth-scale model shown in the cut (Fig. 55) was constructed by Mr. Dewson, and afterwards slightly modified in some particulars by the other two.

Particular attention was paid to making all the parts which affect in any way the disturbances of the reciprocating parts, exactly one-eighth scale. The following changes were made for convenience in construction, and it will be seen that they can have no effect on the subject under discussion. The frame is made of a single piece of cast iron, to which the driving axle boxes are rigidly attached.

The wheels are also made of one casting, and without spokes, with two circular slots, diametrically opposite each other, one to admit the fastening on of the counterweights, and the other to compensate for the loss of metal in cutting the first. Instead of placing the steam chests on top of the cylinders they were placed on the inside, the valve moving in a vertical instead of a horizontal plane. Also certain changes were made in the main rod and the parallel rod for the sake of convenience of construction, as follows: The main rod was split, and the cross-head placed between the two parts, and the piston rod projects through the cross-head, and runs in a fixed bearing, fastened to the frame. The model, as thus far described, weighs seventy-four pounds, whereas, in order to correspond to the weight of the locomotive, it should weigh 156 pounds. Hence a bar of iron of eighty-two pounds was fastened to it in such a position that the forward end, when supported at the centre of the truck should weigh 58.6 pounds, thus bringing the centre of gravity 14″.41 from the centre of the truck and in the same relative position as in the full-sized machine.

The following are the various weights and dimensions of the model, used in calculating the counterweights: —

Weight of crank pin	0.277 lbs.
" " connecting rod	0.598 "
" " piston, piston rod, etc.	0.832 "
" " total driving masses	1.707 "
" " coupling masses	0.598 "

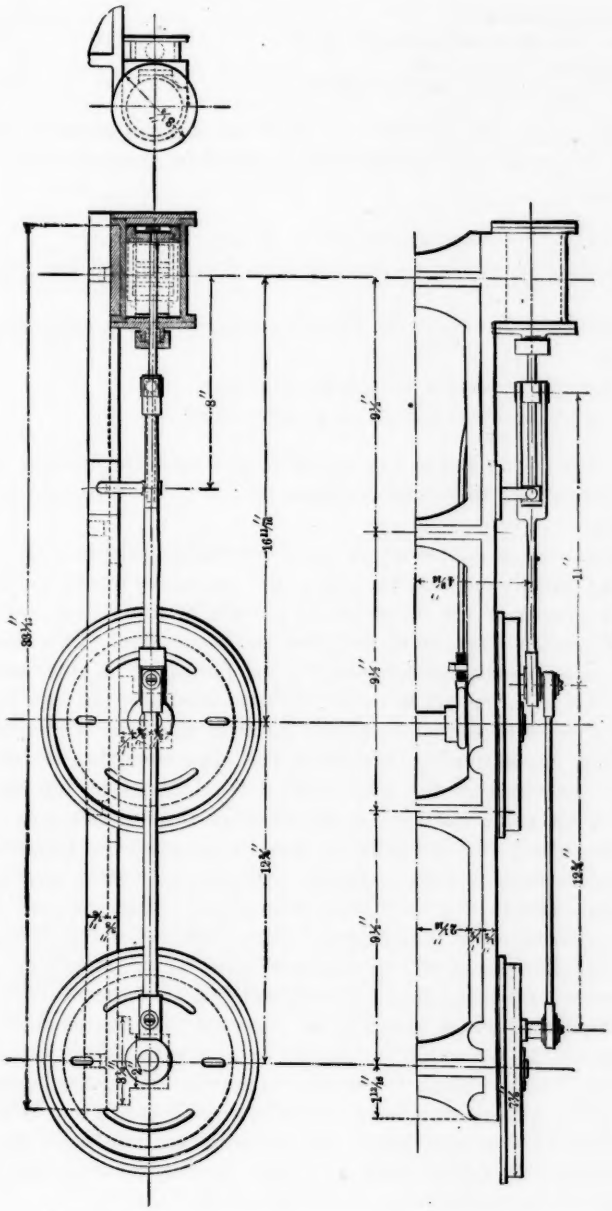


FIG. 55.

Length of connecting rod	10″.953
Distance of centre of gravity from forward end	7″.07
Distance apart of cylinder axes	9″.125
Distance apart of centre lines of parallel rods	10″.25

There are five different motions which the locomotive would receive through the action of the reciprocating parts if free to obey them; they are as follows: —

1° Jerking, a forward and backward motion.

2° Nosing, an oscillation about a vertical axis through the centre of gravity.

3° Galloping, an oscillation about a horizontal axis at right angles to the track.

4° Pounding, a vertical up and down motion.

5° Rolling, an oscillation about a longitudinal axis.

Since the nosing and rolling are dependent upon the leverage of the acting forces, they are evidently greater for outer than for inner cylinder machines.

In practice, it is customary to put the counterweight with its centre of gravity directly opposite the crank pin, and in the wheel, so that the centre of gravity of the reciprocating parts is not directly opposite the centre of gravity of the counterweights, but to one side. This evidently forms a set of equal and opposite parallel forces, or, in other words, a statical couple, which tends to increase the nosing. We can balance the mean throw of the reciprocating parts at the dead points on one side of the locomotive by the use of two counterweights, a large one placed in the wheel on the same side of the locomotive, and opposite the crank pin, and a small one in the wheel on the opposite side of the locomotive which shall throw in the same direction as the reciprocating parts, and we thus obtain a system of three parallel forces, and, by proportioning them so that they shall balance each other, we shall obtain the correct balance for the horizontal throw. Whether this is the best method to follow or not, will be discussed later; we will merely note here that since we are using larger counterweights than the other method would require, it would naturally be expected that the pounding and rolling would be somewhat increased; as to how far this is an evil will be discussed later. Since the cranks on opposite sides of a locomotive are at right angles to each other, we have, in each driver, one large and one small counterweight, which can be combined in a single resultant counterweight, the radius of whose centre of gravity makes a determined angle with the prolongation of the crank radius.

In order to balance the jerking and nosing at the same time, we can imagine exactly opposite the driving and coupling masses Q_t and Q_k, counterweights O_t and O_k of equal magnitudes, and at the same distance r from the axis (Fig. 56). The operation of these masses and counterweights balance each other entirely. We can divide these counterweights into two parts, which come in the driving wheels according to

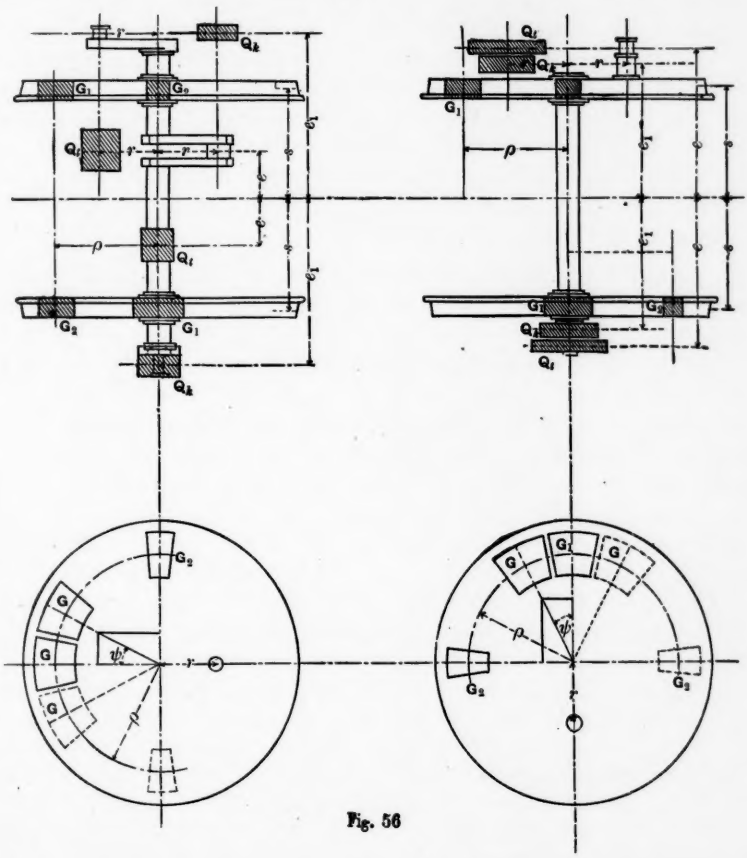


Fig. 56

their leverages, and which, together, are equal to the counterweight referred to (one of them is, however, positive, and the other negative), and which exert the same turning moment about the axis. Change these weights so that they may have the same moment, and be at the required distance ρ from the axis, and we have thus obtained the proper counterweights.

Let $2e$ = distance apart of the cylinder axes, and of the imaginary counterweights.

$2e_1$ = distance apart of the centre of gravity of the corresponding coupling masses.

$2s$ = distance apart of the tracks, or middle of the wheels.

G_1 = the counterweight which should come opposite the crank pin, and on the same side as the parts to be balanced, and G_2 = the weight which should come in the other wheel. ρ is the proper distance of the centre of gravity of the weights G_1 and G_2 from the axis, and r = the length of the crank. It is obvious that we cannot put these imaginary counterweights in the positions referred to above, but must place them so that their centres of gravity shall lie in the plane of the middle of the wheel. This we can do by applying the principle of leverages, and we have the correct counterweights expressed by the following equations: —

$$G_1 = \frac{r}{\rho}\left[O_i\frac{s+e}{2s} \pm O_k\frac{s+e_1}{2s}\right], \quad \cdots\cdots\cdots \quad (1)$$

$$G_2 = \frac{r}{\rho}\left[O_i\frac{s-e}{2s} \mp O_k\frac{e_1-s}{2s}\right], \quad \cdots\cdots\cdots \quad (2)$$

the upper signs referring to the case when the connecting rod and the parallel rod are attached to the same crank pin, and the lower when the crank pins are 180° apart. The left-hand figure shows the case of inner cylinders, and the right-hand that of outer.

These equations give the total counterweights to be used, and these are to be divided between the driving and the coupled wheels.

Let G_1' and G_2' be the weights to be put in the driving wheel, and G_1'' and G_2'' those to be put in the coupled wheel.

$$\therefore\ G_1 = G_1' + G_1'',$$

$$\text{and}\ G_2 = G_2' + G_2''.$$

Let the coupling masses Q_k be considered as made up of R_k and C_k, the latter being the equivalent weight of the coupling crank concentrated at the crank pin, and the former the weight of the rod. Then the following equations will evidently be true: —

$$G_1' = \frac{r}{\rho}\left\{O_i\frac{s+e}{2s} \pm \tfrac{1}{2}R_k\frac{e_1+s}{2s}\right\},$$

$$G_1'' = \pm\frac{r}{\rho}\left\{\tfrac{1}{2}R_k + C_k\right\}\frac{e_1+s}{2s},$$

$$G_2' = \frac{r}{\rho}\left\{ O_i \frac{s-e}{2s} \mp \tfrac{1}{2} R_k \frac{e_1 - s}{2s} \right\},$$

$$G_2'' = \frac{r}{\rho}\left\{ \tfrac{1}{2} R_k + C_k \right\} \frac{e_1 - s}{2s}.$$

We may reduce these to a single resultant, using the parallelogram of forces, and we thus obtain

$$G' = \sqrt{G_1'^2 + G_2'^2},$$

$$G'' = \sqrt{G_1''^2 + G_2''^2};$$

and if ψ_1 is the angle between the radius of G' and G_1', and ψ_2 is the angle between G'' and G_1'', we have

$$\tan \psi_1 = \frac{G_2'}{G_1'},$$

$$\tan \psi_2 = \frac{G_2''}{G_1''}.$$

While Mr. Dewson made but few experiments, Mr. Reynolds made quite a number, which included those of Mr. Dewson.

The different methods of counterbalancing upon which he experimented will be denoted respectively by *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, and they may be described as follows:—

A. No counterweights.

B. Method used by one of the locomotive works, which may be described as follows:—

"For the main drivers, place opposite the crank pin a weight equal to one-half the weight of the back end of the connecting rod plus one-half the weight of the front end of the connecting rod, piston, piston rod, and cross-head. For balancing the coupled wheels, place a weight opposite the crank pin equal to one-half the parallel rod plus one-half of the weights of the front end of the main rod, piston, piston rod, and cross-head. The centres of gravity of the above weights must be at the same distance from the axles as the crank pin."

C. The rule given by D. K. Clark, and followed by another locomotive works, is the following:—

"Find the separate revolving weights of crank pin, crank pin boss, coupling rods, and connecting rods for each wheel, also the reciprocating weight of the piston and appendages, and one-half the connecting rod, divide the reciprocating weight equally between each wheel, and add the part so allotted to the revolving weight on each wheel; the sums

thus obtained are the weights to be placed opposite the crank pin, and at the same distance from the axis. To find the counterweight to be used when the distance of its centre of gravity is known, multiply the above weight by the length of the crank in inches and divide by the given distance."

This rule differs from the preceding in that the same weight is placed in each wheel.

D. Method of counterbalancing already explained in this paper.

E. Method used by another locomotive works, which may be described as follows: —

"S = one-half the stroke.

"G = distance from centre of wheel to centre of gravity in counterbalance.

"w = weight at crank pin to be balanced.

"W = weight in counterbalance.

"f = coefficient of friction so called.

$$W = \frac{S \times \left(w - \frac{w}{f}\right)}{G},$$

$f = 5$ in ordinary practice.

"The reciprocating weight is found by adding together the weights of the piston, piston rod, cross-head, and one-half of the main rod. The revolving weight for the main wheel is found by adding together the weights of the crank pin hub, crank pin, one-half of the main rod, and one-half of each parallel rod connecting to this wheel; to this add the reciprocating weight divided by the number of wheels.

"The revolving weight for the remainder of the wheels is found in the same manner as for the main wheel, except one-half of the main rod is not added.

"The weight of the crank-pin hub and the counterbalance does not include the weight of the spokes, but of the metal inclosing them. This calculation is based for one cylinder and its corresponding wheels."

F. Method pursued by another works, which is as follows: "Ascertain as near as possible the weights of crank pin, additional weight of wheel boss for the same, add side rod, and main connections, piston rod and head, with cross-head on one side: the sum of these multiplied by the distance in inches of the centre of the crank pin from the centre of the wheel, and divided by the distance from the centre of the wheel to the common centre of gravity of the counterweights is taken for the total counterweight for that side of the locomotive which is to be divided among the wheels on that side."

G. Method pursued by another locomotive works is as follows: "Balance the wheels of the locomotive with a weight equal to the weights of crank pin, crank-pin hub, main and parallel rods, brasses, etc., plus two-thirds of the weight of the reciprocating parts (cross-head, piston and rod and packing)."

H. Method pursued by another locomotive works: "Balance the weights of the revolving parts which are attached to each wheel with exactness, and divide equally two-thirds of the weight of the reciprocating parts between all the wheels. One-half of the main rod is computed as reciprocating, and the other half as revolving weight."

The method of making the experiments was as follows: To the front end of the model a long rod was attached, and, fastened in the end of this, was a needle point, which was caused to trace its motion on a piece of smoked glass, slowly moved parallel to, and at right angles to the longitudinal axis of the machine. A sinuous line was thus obtained which showed the jerking or nosing according to the direction in which the glass was moved. The amount of either was then measured with the aid of a magnifying glass. Knowing the distance of the middle point from the centre of gravity of the machine, the angle of nosing was calculated. The results obtained for the jerking and nosing with the different methods of counterweighting will now be given.

JERKING IN INCHES.

Rev. per Min.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
100	0.06	0.006	0.012	0.012	0.015	0.018	0.015	0.015
150	0.07	0.01	0.012	0.012	0.02	0.017	0.018	0.018
200	0.07	0.012	0.01	0.01	0.02	0.017	0.018	0.018
250	0.08	0.014	0.01	0.01	0.023	0.015	0.02	0.018
300	0.08	0.015	0.01	0.014	0.025	0.015	0.018	0.018

NOSING IN INCHES.

Rev. per Min.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
100	0.20	0.01	0.01	0	0.04	0.028	0.04	0.038
150	0.18	0.01	0.01	0	0.035	0.030	0.035	0.035
200	0.16	0.015	0.012	0	0.033	0.030	0.032	0.033
250	0.15	0.015	0.015	0	0.03	0.030	0.030	0.030
300	0.12	0.017	0.015	0	0.03	0.032	0.030	0.028

ANGLE OF NOSING IN MINUTES OF ARC.

Rev. per Min.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
100	36.30	1.81	1.81	0	7.24	5.07	7.24	6.88
150	32.67	1.81	1.81	0	6.33	5.43	6.33	6.33
200	29.40	2.71	2.17	0	5.97	5.43	5.99	5.97
250	27.21	2.71	2.71	0	5.43	5.43	5.43	5.43
300	21.78	3.07	2.71	0	5.43	5.99	5.43	5.07

REMARKS ON THE SPECIAL TESTS.

A. The pointer travelled in ellipses whose major axes were at right angles to the longitudinal axis of the machine, and whose minor axes moved from one side of the centre line to the other by a small amount. At high speeds there was a marked tendency to roll.

B. After making the experiments, with the results reported in the table, another set was made with a brake applied to the drivers, in order to determine whether the disturbances were affected or not by the loading or unloading of the drivers. The results, however, were identical with those obtained without the brake.

C. These tests were also repeated with the brake, but the results were identical with those obtained without the brake.

D. The results given in the table were obtained by using the single resultant counterweight calculated as already explained. Afterwards the tests were repeated, using the two separate counterweights, as already described, in each wheel.

It will be evident from a perusal of the results that this method effectually destroys the nosing.

The counterweights, however, are heavier than those used in several of the other systems, and it would seem reasonable to conclude that the pounding would be increased; that it is not increased to an injurious extent will be made evident from some experiments of which an account is given later in this paper.

I understand that a locomotive made at the Canadian Locomotive and Engine Co.'s Locomotive Works at Kingston, Ont., Canada, was counterweighted in this way, and was considered a very smooth-running engine.

The method itself is given by Rankine and by Grove, but does not seem to have been tried in locomotive works, with the single exception already mentioned.

E. The counterweights used in this method of balancing are considerably smaller than those used in the preceding methods. Moreover, the increase in the nosing and jerking shows that the counterweights are too light to balance the disturbances successfully. In this case, however, the tendency to roll was considerably less.

Pounding.

It seemed desirable to investigate these different methods of counterweighting in regard to their effect upon the pounding. Two series of experiments were made for this purpose, — one by Mr. Reynolds, and the other by Mr. Smith.

The work done by Mr. Reynolds may be described as follows: —

The model was placed upon a wooden frame in such a way that the wheels were free to revolve as before, and the whole was placed upon platform scales. The mode of conducting the experiment was as follows: The whole was weighed at rest, and then after it was set in motion the weight was ascertained, which it was necessary to add to keep the scale arm from leaving its seat.

Since the throw is the same upward as downward, this extra weight subtracted from the original weight should give the amount indicated on the scale arm, when the arm just stays against the upper stop. This it did in every case.

These experiments do not, of course, show the actual force of the vertical throw in pounds, but merely give relative results, thus showing which of the methods already detailed is the best in this respect.

The results are given in the following table: —

Rev. per Min.	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
100		1.5	1.25	1	1	1	1	1.5
150		2.5	2.75	1.75	1.5	2	1.75	2.5
200		4.25	4.25	2.75	2.5	3.75	3.25	3.75
250		6.75	6	4.5	4	4.75	5.50	5.25
300		8	7.5 to 9	6.5 to 7.5	5.75 to 6.5	6 to 7	6 to 7	7 to 8

These results would seem to show that the pounding is not materially greater in *D* than in the other methods in use. Mr. Smith attempted to obtain more nearly absolute values by directly weighing the pound on the driving boxes by means of springs.

The apparatus used is shown in the accompanying cut (Fig. 57). It will be seen that the driving boxes are in two parts. Now, by removing the screws which were intended to fasten the lower to the upper half, we may have the pressure which would otherwise cause a tension in these screws transmitted through the weighing springs placed beneath, and thence to the frame by means of the horizontal piece *AB*, and the bolts *CC'*. The only changes made in the model itself to secure this arrangement were to remove the bolts fastening the two halves of the

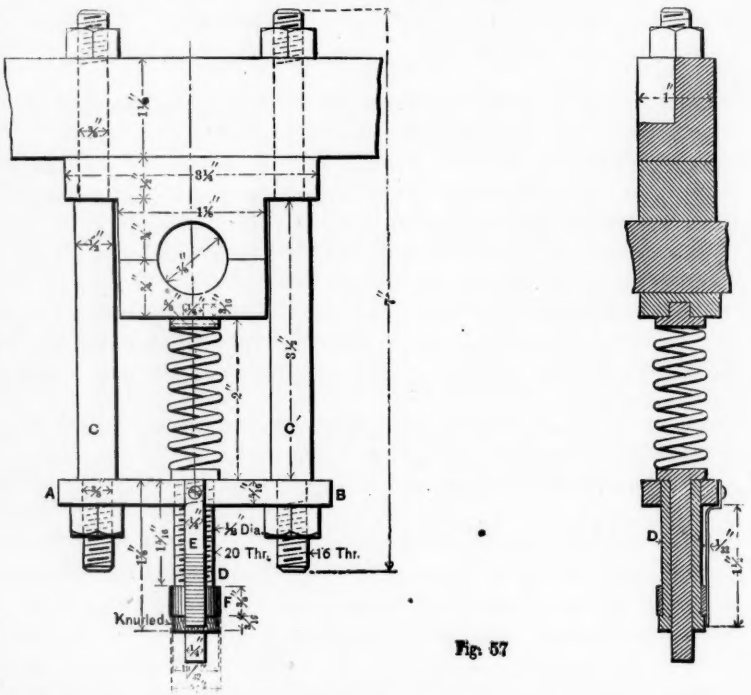


Fig. 57

driving box together, and to replace the bolts which attach the boxes to the frame by the ones *CC'* shown in the drawing, and which perform the double duty of supporting the upper part of the frame and of transmitting to it the weight which may come on the spring.

These weighing springs were graduated to a scale of sixty pounds to the inch. The head of the spring was provided with a nipple, fitting into a corresponding hole in the driving box, and the elongated tail piece passed through the micrometer screw *D*, on which the spring

rests, thus making the different parts of the apparatus stable in position. From the spring the pressure was transmitted through the micrometer screw to the horizontal piece *AB*. These screws were made with a pitch of twenty threads to the inch and accurately fitted to the corresponding tapped holes in the supporting pieces. With the screw is the micrometer device, arranged as follows: To the piece *AB* is fastened the brass scale *E*, graduated to twentieths of an inch, corresponding to the pitch of the screw. Next to the milled head of the screw is a brass collar *F*, divided circumferentially into twenty-five equal parts. Now, since each revolution of the screw causes a vertical movement of $\frac{5}{100}$ of an inch, each of these divisions corresponds to $\frac{2}{1000}$ of an inch. Readings can be taken to $\frac{1}{1000}$ of an inch, and the scale might easily be read to $\frac{1}{5000}$ of an inch, if the other conditions of the experiments should make such precision valuable. A difference of $\frac{1}{1000}$ of an inch in the reading corresponds to a compression of $\frac{6}{100}$ of a pound.

The method of conducting the experiments was as follows: The counterweights which it was desired to investigate were first placed in the wheels. Then a micrometer reading was taken under each wheel while the machine was at rest, these readings being used as datum readings for the succeeding ones, whose excess over these gave the pressure due to the centrifugal action of the reciprocating parts and counterweights combined.

The experiments of Mr. Smith were not, however, carried to a sufficient degree of completeness to render them suitable for publication until some farther work is done upon them.

In conclusion it may be said that while method *D* effectually destroys the nosing, and is undoubtedly the best for balancing the horizontal throw, it seems desirable to make more experiments upon the vertical throw, before very decided conclusions can be drawn in this regard.

RELATIONS OF THE PINITE OF THE BOSTON BASIN TO THE FELSITE AND CONGLOMERATE.

By W. O. CROSBY.

In 1880* the writer called attention to the fact that the soft, greenish and somewhat unctuous, amorphous mineral, which is such an interesting constituent of the conglomerate so extensively developed in the vicinity of Boston and which has been frequently mistaken for serpentine, is shown by its ready fusibility not to be magnesian; but that analysis proves that it is essentially a hydrous alkaline silicate of aluminum, and that its physical as well as its chemical characters ally it with the protean species pinite. It was further shown: (1) That the pinite not only contributes largely to the formation of the pebbles and paste of certain parts of the conglomerate, but that it is also found in the sandstone and slate of this region. (2) That its occurrence in the form of pebbles and fragments proves that it must usually, if not always, be regarded as an imported constituent of these fragmental rocks. (3) That the pinite is also often associated with the felsite in and around the Boston Basin, and always in such a way as to show that it is indigenous in that rock and has resulted from its alteration, the pinite having its best development near the surface of the felsite ledges or along the joint cracks traversing the felsite.

The fine exposures, then recently made, on Central Avenue, Milton, of a purplish felsite largely changed, superficially and along the joint planes, to a green pinite, and surrounded and in part covered by a distinct pinite conglomerate, was described in considerable detail; and analyses were given to show that the pinite in the conglomerate is essentially identical with that in the felsite, the felsite ledge being plainly the source of the pebbles of both felsite and pinite composing the conglomerate. It was also pointed out that not only the occurrence of the pinite débris in the fragmental rocks, which are believed to be wholly of Primordial age, but also its superficial position in the felsite, where, as on Central Avenue, that rock is covered by the conglomerate, proves that the formation of the pinite must date largely, if not wholly, from Primordial times; the facts seeming to warrant or to

* Am. Jour. Sci., XIX., pp. 116–122. Occas. Papers, Boston Soc. Nat. History, III., pp. 89, 220–221, 269–272.

plainly suggest the conclusion that, in Primordial and pre-Primordial times, the felsites, to a considerable depth, were changed by the atmospheric agents, not to kaolin, as generally at the present time, but to or toward pinite; and that subsequently this decomposition-product was, for the most part, swept away by the sea in which were deposited the Primordial conglomerate and sandstone.

A thorough study of the geology of the Boston Basin carried on during the past four years has brought to light no facts materially controverting any of these general conclusions concerning the origin and geological relations of the pinite; but, on the other hand, several striking confirmations of them have been observed; and the principal object of this paper is simply to add the weight of some of this new evidence to the argument as made up nearly a decade since.

Something more than a year ago my attention was called to an important development of pinite on the north side of the Boston Basin, in Medford, by Dr. D. F. Lincoln; and he kindly assisted me in obtaining typical specimens of the pinite and associated rocks.

North of High Street, in West Medford, hornblendic granite is the prevailing rock. It intersects the Archæan quartzite and diorite at some points, and is itself traversed by numerous dikes of diabase, some of which are very large. Southward, the granite becomes very fine grained, nearly or quite micro-crystalline, and is overlaid, possibly without any important break, by a greenish gray to gray felsite. The felsite is often indistinctly porphyritic, and occasionally concretionary or spherulitic. The junction of the granite and felsite appears to run in an east-northeast direction, crossing Allston, Mystic, Woburn, and Purchase Streets, north of High Street. This contact is not well exposed, because both the granite and felsite are here overlaid by a belt of conglomerate 300 to 500 feet wide, dipping south, or away from the granite, about 20°, and changing in that direction to a conformably overlying quartzite which has a somewhat greater breadth than the conglomerate. The felsite is repeated in prominent ledges south of these sedimentary rocks by a fault along the line of High Street.

Although the conglomerate is chiefly composed of pebbles of quartzite, granite and felsite, it also encloses fragments of pinite and finely comminuted material of the same general character. But the only satisfactory exhibition of the relations of the pinite to both the felsite and conglomerate, in Medford, was afforded very transiently by a trench which was excavated for a water-pipe in a small court running from the west side of Mystic Street, 400 or 500 feet north of High Street. This

trench crossed obliquely the junction of the granite and felsite at a point where it almost exactly coincides with the contact between the felsite and conglomerate; so that all of these rocks were clearly exposed in one short and continuous section. The granite is micro-crystalline and not readily distinguished from the felsite; and the latter is, superficially, or next to the conglomerate, largely changed to a deep green, typical pinite. The alteration is not uniform, being more marked at some points than at others; but between the pure pinite and the felsite there would appear to be a perfect gradation, except that where the felsite is not affected by the pinite alteration it is more or less kaolinized, so that no unaltered felsite was observable at this point. Fragments of the different grades of pinite, as well as of the felsite and granite, were observed in the conglomerate, which was evidently deposited over a deeply weathered or altered ledge of felsite and granite, the débris of which contributed largely to its formation. Not only the compact, but also the porphyritic and spherulitic varieties of the felsite are represented in the pinite. It is noticeable, however, that the pinite alteration is virtually limited to the felsitic ground mass of the rock, having rarely affected the porphyritically developed feldspars or the feldspathic spherules, for these are still white, and occasionally retain the hardness of feldspar, although very generally kaolinized.

The pinite evidently occurs here under essentially the same conditions as on Central Avenue, Milton; and its connection with the felsite was so clearly exposed as to make it desirable to further test its derivation from that rock by analysis. It was first sought to compare in this way the pinite and the unaltered felsite; but this plan was reluctantly abandoned on account of the general kaolinization of the felsite not affected by the pinite alteration. The comparison is therefore made between the most typical pinite obtainable in the trench and felsite that appeared to be, as judged by its position, color, and hardness, only partially altered to pinite. Through the kindness of Dr. T. M. Drown, repeated analyses of these two types have been made by the class of 1889 of the Massachusetts Institute of Technology. The results are tabulated below. The first column of figures indicates the number of separate determinations of each constituent; and the second, third, and fourth columns, the minimum, maximum, and mean results obtained. The different determinations were, to a large extent, made with independent specimens; and the considerable variations observed in some cases are undoubtedly due in large part to original differences in the material. Each table is followed by the names of the students by whom the analyses were made.

FELSITE, ALTERED.

Constituents.	No.	Minimum.	Maximum.	Mean.
SiO_2	11	69.98	74.82	73.37
$Al_2O_3 + Fe_2O_3$	8	17.30	17.95	17.71
K_2O	6	2.79	4.10	3.54
Na_2O	6	1.10	4.35	2.45
CaO	8	0.27	0.43	0.33
MgO	7	0.43	0.54	0.47
H_2O	6	1.30	2.10	1.65
Moisture.	6	0.35	0.40	0.38
				99.90

EDWARD J. BEACH, WILLIAM S. DAVENPORT, EDWARD M. HARRINGTON.

PINITE.

Constituents.	No.	Minimum.	Maximum.	Mean.
SiO_2	13	44.51	54.04	48.16
$Al_2O_3 + Fe_2O_3$	9	34.71	36.83	36.23
K_2O	7	7.95	10.01	8.65
Na_2O	7	0.16	0.72	0.39
CaO	10	0.17	0.43	0.28
MgO	9	0.56	1.30	0.91
H_2O	9	4.31	4.76	4.51
Moisture.	6	0.34	0.41	0.38
				99.51

FRED. CRABTREE, FRED. L. HOPKINS,
HARRISON G. DYAR, C. W. SMITH,
FRANK H. THORP.

The analyses of felsite indicate a somewhat hydrated, acid rock, containing some free silica and both potash and soda feldspars. The magnesia and, perhaps, the lime may be referred to microscopic hornblende, the composition throughout being analogous to, although probably less acid than, that of the associated micro-granite. A notable loss of the alkaline constituents has evidently already taken place; and it seems probable that the silica thus liberated has not been wholly eliminated from the rock. The conversion of this altered but still acid felsite to pinite involves, besides the increased hydration, a very important diminution of silica and soda, and, in consequence, a marked relative

increase of alumina and potash. This gives very nearly the normal composition of pinite, if we refer several per cent of silica to the original and insoluble free silica or quartz.

The relations of the pinite to both the felsite and conglomerate have also been clearly exposed by recent quarrying at a new locality on the south side of the Boston Basin. This is in the Mattapan district of Dorchester, on Norfolk Street, and immediately south of the New York and New England Railroad. The prominent ledge on the east side of the street has long been known by the writer to exhibit the contact between a dark green and nearly compact melaphyr on the west, and a light gray to red compact and finely banded felsite on the east. The contact of the melaphyr and felsite at this place is a fault with the melaphyr on the down-throw side. On fresh surfaces, especially, the felsite is more or less greenish and shows in its softness, also, considerable alteration toward pinite; while recent blasting has shown that the melaphyr is overlaid at the highest point and next to the fault by a small outlier of conglomerate with intercalated layers of purplish slate. The conglomerate, which is in part a fairly good breccia, is composed almost wholly of pinite and felsite, and it is very clear that this detritus has been derived from the felsite area immediately adjoining.

The facts appear throughout to support the general conclusion that the fragmental pinite in the conglomerate, as well as the principal part at least of that still associated with the felsite, dates from Primordial times. A careful search has been made for evidence of the alteration of felsite pebbles to pinite after their enclosure in the conglomerate. It appeared on first examination as if an example of this had been found on Blue Hill Avenue, in Milton. About one-half mile south of the Neponset River, the avenue crosses an area of felsite showing the pinite alteration to some extent. The felsite is surrounded and probably overlaid by a distinct and beautiful conglomerate, in which felsite pebbles largely predominate; although a very typical dark green pinite occurs prominently in both pebbles and paste. An occasional pebble, however, consists of a centre or nucleus of unaltered gray or purplish felsite surrounded by an indistinct zone or envelope of pinite, which thus has the appearance of being indigenous in the conglomerate. But, while it is possible that these pebbles have been superficially changed to pinite, since their separation from the parent ledges of felsite; the irregular thickness of the pinite crusts, indicating mechanical wear, and the fact that, with these rare exceptions, the felsite pebbles show no superficial alteration whatever, leave little or no doubt that the alteration was wholly anterior to their enclosure in the conglomerate.

*THE STRENGTH OF THE MICROPHONE CURRENT AS INFLUENCED BY VARIATIONS IN NORMAL PRESSURE AND MASS OF THE ELECTRODES.**

By ANNIE W. SABINE, A.M., S.B.

The experiments described in the present paper, undertaken at the suggestion of Professor Cross, constitute a study of the variation of the current in the secondary circuit of a microphone transmitter, as related to variations in the normal pressure and in the mass of the electrodes of the microphone. They form a continuation of work of a similar character which has been prosecuted in the Rogers Laboratory during the past few years, and a portion of which has already been presented to the Academy. (See Proc. Am. Acad., Vol. XXI., p. 248; Ibid., Vol. XXIII., p. 228; also Tech. Quarterly, I., p. 238.)

The instruments used were similar to those previously employed by Messrs. Patterson and Tucker, and described in the latter of the two articles just referred to. The electrodynamometer was calibrated by means of a Hartmann galvanometer, using reversals in the ordinary manner so as by four readings to eliminate the effect of the earth's magnetism on the suspended coil.

The microphone contact was set into vibration by the sound of a stopped organ-pipe (C_4 of 512 vibrations) kept as constant as possible by means of an air-blast furnished with a regulating air-chamber. Weights are gradually added to the upper (anvil) electrode, so that the mass of this and its pressure on the lower electrode were thereby increased by measured amounts. The weights added were usually in the form of thin copper washers weighing $\frac{8}{10}$ of a gram each, though fractions of this weight were used in some cases. One chromic acid cell was used as a battery.

The character of the results obtained will be seen by an inspection of Figure 1, which gives the curve showing the relation between the normal pressure and the resulting current, with electrodes of the materials employed in the Blake transmitter, viz., a platinum hammer and a hard carbon anvil electrode. The abscissas represent the normal pressures, *i.e.*, the added weights, and the ordinates the currents pro-

* Read at a meeting of the American Academy of Arts and Sciences, Nov. 14, 1888.

duced in the secondary. The data from which this curve is constructed will be found in the following table. The load is given in terms of the arbitrary unit employed; the currents are given in milliampères.

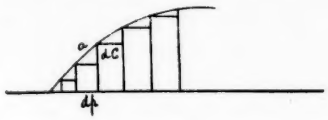
TABLE.

Load.	Current.	Remarks.
0	0	
·5	.18	
1.0	.46	Loud, good quality, fluttering.
1.5	.48	" " " "
2.5	.56	" " " "
3.0	.49	
3.5	.45	Faint, good quality.
4.0	.33	" " "
4.5	.21	
5.0	.19	

The curve shows a rapid rise at first, as the mass of the anvil electrode, and with it the pressure between the electrodes, is increased, which rise soon reaches a maximum, the curve then falling off rapidly at first, more slowly afterwards.

The nature of the curve is interesting, and requires explanation. In his article already referred to, Mr. G. W. Patterson, who obtained similar results to my own, considers the curve to be composed of two separate branches, the rising portion of the curve corresponding to a motion of the electrodes sufficient to break the circuit, and the falling portion to the case when the pressure is too great to allow this to occur. The curve (Am. Acad. Proc., Vol. XXIII., p. 235, Fig. 4; Tech. Quarterly, I., p. 238) constructed upon this hypothesis greatly resembles one of the experimental curves shown in Figure 3 of the same paper. There is less resemblance, however, to the lower curve in Figure 3, and but little to the curve shown in Figure 1 of this article, which was obtained under exceptional conditions of quietness of the piers upon which the apparatus was placed. The sound in a receiving telephone placed in the secondary circuit is so harsh for this portion of the curve, that one might well infer that actual breaks occurred; but this is very doubtful, and such breaking is certainly not essential to the production of the results which are obtained. In fact, the article referred to assumes that the varying pressure on the contact due to the action of the given sound-waves will always have the same maximum value, $\pm\delta$. This would be approximately true were the normal pressure between the two electrodes alone to be varied, but the effect of the addition of weights, as in the method of experiment adopted, is to increase the

mass at the same time that the normal pressure is increased, and under these circumstances the effect of a sound-wave of given intensity will necessarily be to give to the corresponding pressure-variation a variable value, increasing with the added mass, and hence, with the form of apparatus used, as the normal pressure is greater. The effect of this will be to cause at first a gradual increase of current in the secondary, which increase is succeeded by a diminution of current when the mass



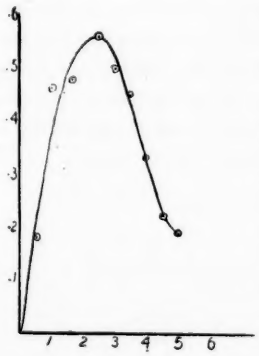


FIG. 1.

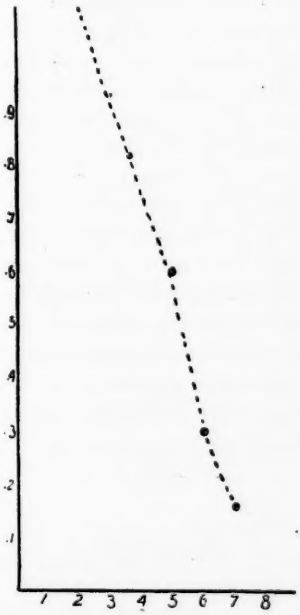


FIG. 2.

is still further increased. This will be apparent from an inspection of the curve shown in Figure 2, which illustrates in a general manner the relation of the pressure between the electrodes to the current in the primary circuit.

In this the momentary changes in pressure, Δp, $\Delta p'$, $\Delta p''$, etc., due to the sound-waves, and corresponding to loads and normal pressures p, p', p'', etc., have increasing values within certain working limits,

owing to the increasing mass of the anvil electrode. The currents in the primary also increase, though at a gradually diminishing rate, as the pressure between the electrodes is increased, so that the increments of current, Δc, $\Delta c'$, $\Delta c''$, corresponding to the pressure-changes Δp, $\Delta p'$, $\Delta p''$, have increasing values up to some point, as a, after which they decrease. This being the case, it is evident that the current in the secondary will at first increase to a maximum, and afterwards diminish, since the currents in the secondary corresponding to pressures p, p', p'', etc., will be proportioned to Δc, $\Delta c'$, $\Delta c''$, etc., and this is precisely the curve which is obtained in the experiments. The explanation just offered seems therefore to be the true one.

The matter was still further tested by carrying out a set of experiments similar to those already described, except that the variations in normal pressure were brought about by means of a spring instead of by adding weights. In such a case the successive values of Δp in the curve (Fig. 2) would be of the same magnitude, while Δc would continually diminish. The current in the secondary should therefore have its maximum value when the initial normal pressure is least, and continually diminish as the pressure becomes greater.

The experimental results verified this conclusion, as will be seen by reference to Figure 3, in which the normal pressures are represented by abscissas, and the currents in the secondary by ordinates, as before. The curve is approximately a straight line. It is possible that the deviations from this are due to instrumental imperfections, as the apparatus used did not allow of more than an approximate determination of the pressure applied by the spring.

ROGERS LABORATORY OF PHYSICS,
June, 1888.

*RESEARCHES ON MICROPHONE CURRENTS.**

By CHARLES R. CROSS, S.B., and ANNIE W. SABINE, A.M., S.B.

In continuation of studies described in former papers from the Rogers Laboratory, the authors have observed the variations in the secondary current which occur under different circumstances as to mass and normal pressure when the material of the electrodes of a microphone is varied. The methods and apparatus employed were identical with those described in the paper immediately preceding the present one.

In the first series of experiments both electrodes were made of the same material, the hammer electrode being a very small button, and the anvil electrode a larger one, as in the Blake transmitter. As the mass and pressure upon the anvil electrode were varied, the currents in the secondary at first increased up to a maximum, and afterwards diminished, as shown in the article just referred to, as well as in the curves given with the present paper. Tables I. to XVI. give the numerical results obtained, and Figures 1 to 14 are curves showing the relations between the variables, the loads being abscissas, and the corresponding currents in milliampères the ordinates. The unit of weight adopted was $\frac{5}{10}$ of a gram. The remarks in the third column of the tables indicate the nature of the sound heard in a receiving telephone placed in the secondary circuit. The current was in all cases zero when the load was zero.

Table I.

Electrodes. — *Iron*, *Iron*.

Load.	Current.	Remarks.
1	.19	Sound rough and unsteady.
2	.24	Shrill, clear, metallic, unsteady.
3	.16	" " " "

Table II.

Electrodes. — *Platinum*, *Platinum*.

Load.	Current.	Remarks.
1	.43	
2	.62	Quality good; fluttering.
3	.73	" " metallic.
4	.23	" " "
5	.10	" " fluttering.

Table III.

Electrodes. — *Carbon*, *Carbon*.

Load.	Current.	Remarks.
1	.44	Harsh; loud.
2	.63	" "
3	.71	Quality good; fluttering.
4	.67	" " slight fluttering.
5	.27	" " faint fluttering.
6	.18	" " " "
7	.12	" " " "

* Read at a meeting of the American Academy of Arts and Sciences, Nov. 14, 1888.

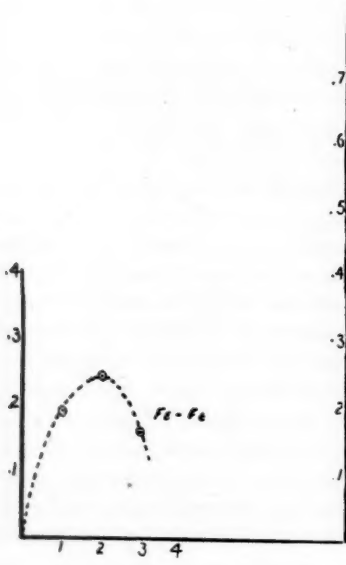


FIG. 1.

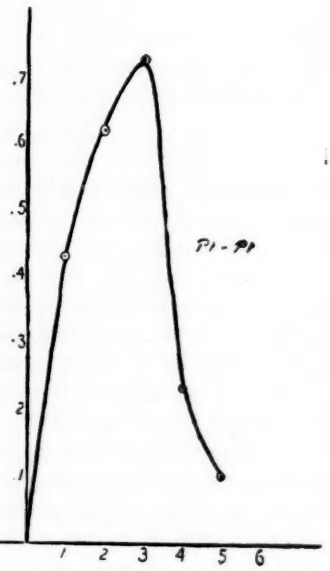


FIG. 2.

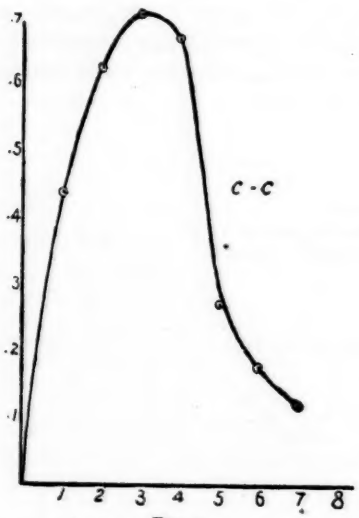


FIG. 3.

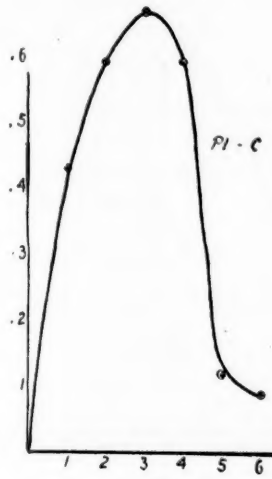


FIG. 4.

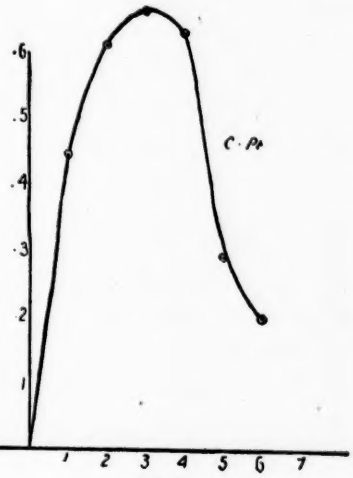
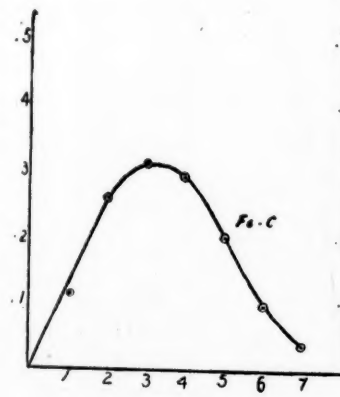


FIG. 5.



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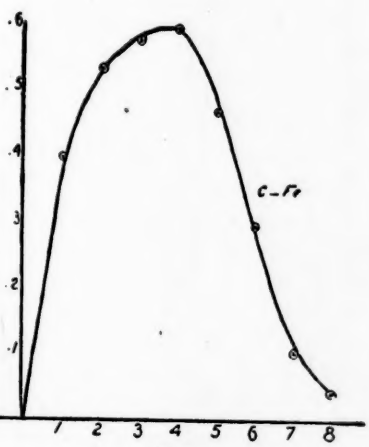

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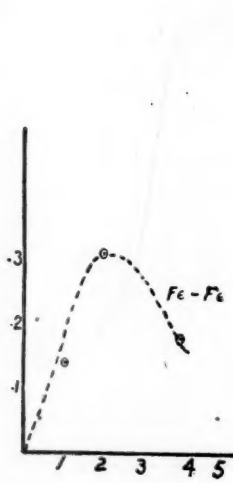

FIG. 8.

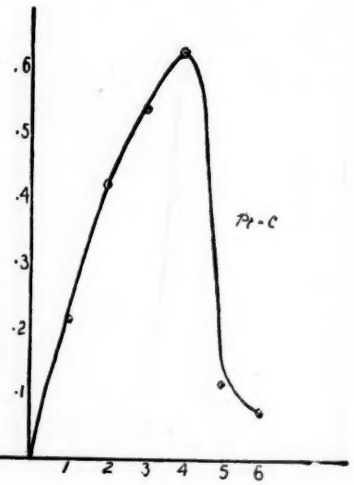

FIG. 9.

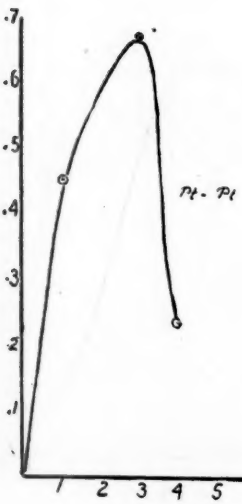

FIG. 10.

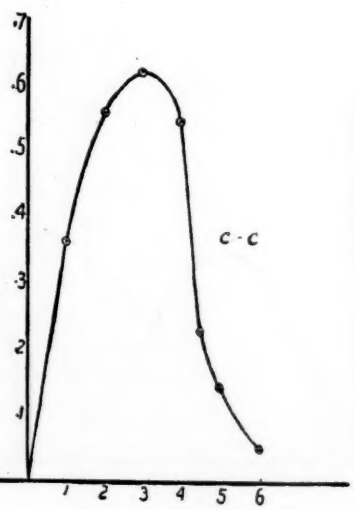

FIG. 11.

Table IV.

Electrodes. — *Platinum, Carbon.*

Load.	Current.	Remarks.
1	.43	Harsh and loud.
2	.59	" "
3	.67	Quality good and clear, some fluttering.
4	.59	" " " " "
5	.12	Faint, fluttering.
6	.09	" "

Table V.

Electrodes. — *Carbon, Platinum.*

Load.	Current.	Remarks.
1	.445	Harsh and loud.
2	.61	Clear; good quality.
3	.66	Clear; some fluttering.
4	.63	Faint; good quality; some fluttering.
5	.29	" " " " "
6	.20	" " " " "

Table VI.

Electrodes. — *Iron, Carbon.*

Load.	Current.	Remarks.
1	.115	Harsh, irregular noise.
2	.260	" " "
3	.310	" " "
4	.290	Clear, good quality; faint.
5	.200	Faint; slight fluttering.
6	.095	Faint.
7	.040	"

Table VII.

Electrodes. — *Carbon, Iron.*

Load.	Current.	Remarks.
1	.395	Harsh and loud.
2	.530	Clear, shrill, good quality.
3	.570	Clear; fluttering.
4	.590	Quality good; slightly harsh.
5	.460	" " " "
6	.290	" " " "
7	.100	Very faint.
8	.040	"

Table VIII.

Electrodes. — *Platinum, Platinum.*

Load.	Current.	Remarks.
1	.450	Harsh and loud.
2	.560	" "
3	.670	Uncertain; sometimes good quality.
4	.230	Harsh; fluttering.

Table IX.

Electrodes. — *Carbon, Carbon.*

Load.	Current.	Remarks.
1	.360	Harsh and loud.
2	.560	Somewhat shrill; good quality.
3	.620	Good quality, somewhat rough.
4	.545	" " fluttering.
4.5	.225	Faint and rough.
5	.140	Faint.
5.5	.050	"

Table X.

Electrodes. — *Iron, Iron.*

Load.	Current.	Remarks.
1	.140	
2	.310	Quality good.
3	.270	
4	.180	

Table XI.

Electrodes. — *Platinum, Carbon.*

Load.	Current.	Remarks.
1	.210	Rough.
2	.420	"
3	.540	Quality good; loud.
4	.630	" " slight fluttering.
5	.120	" " faint fluttering.
6	.070	" " " "

Table XII.

Electrodes. — *Carbon, Platinum.*

Load.	Current.	Remarks.
1	.260	
2	.440	Shrill and loud.
3	.530	Clear, loud, good quality.
4	.620	" " " "
5	.555	Fainter and rougher.

TABLE XIII.

ELECTRODES. — *Iron, Carbon.*

Load.	Current.	Remarks.
1	.240	Sound uncertain.
2	.300	
3	.310	Clear; good quality.
4	.290	" " "
5	.180	" " " faint.
6	.099	" " " "

TABLE XIV.

ELECTRODES. — *Carbon, Iron.*

Load.	Current.	Remarks.
1	.345	Rough, steady.
2	.515	
3	.615	Good quality.
4	.560	" "
5	.235	Faint, rough.
6	.140	Faint, clear.

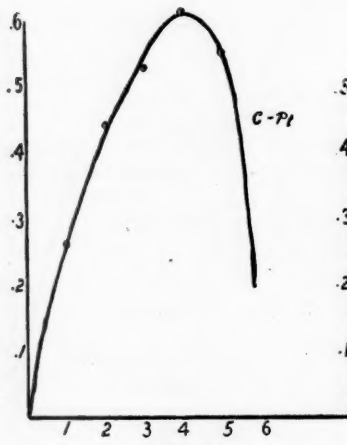

FIG. 12.

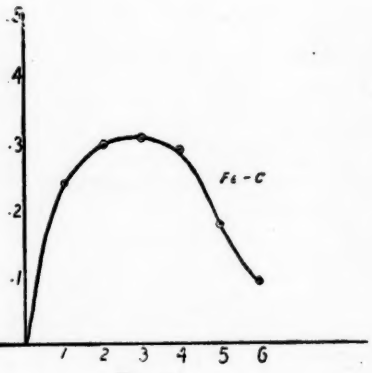

FIG. 13.

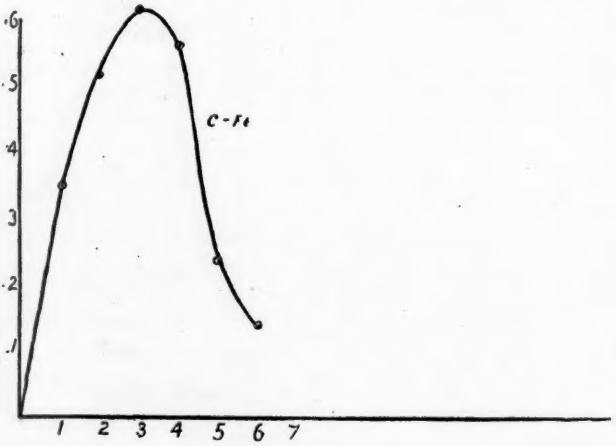

FIG. 14.

TABLE XV.

ELECTRODES. — *Copper, Carbon.*

Load.	Current.	Remarks.
1	.390	Rough and loud.
1.5	.490	" "
2	.590	" "
2.5	.550	" "
3	.250	" "
3.5	.130	" "

TABLE XVI.

ELECTRODES. — *Carbon, Copper.*

Load.	Current.	Remarks.
1	.240	Good quality; fluttering.
2	.520	" " "
3	.600	" " "
4	.660	" " "
5	.240	" " "
6	.090	" " "

Figures 1 to 3 show very well the characteristics of the substances iron, platinum, carbon. Comparing the curves for carbon and platinum (Figs. 2, 3), it will be seen that the maximum current obtained under the conditions of the experiment was about the same in both cases. But the current falls off far more rapidly with platinum as the pressure is further increased, thus giving to carbon a greater working range of pressure-variation within which it can be practically used in a microphone transmitter, a fact long since recognized in practice. Iron (Fig. 1) has a considerable range, but the current produced is not great.

Tables IV. to VIII., and Figures 4 to 8, illustrate the results obtained when the electrodes were of different materials, the substance of which the anvil electrode was made being the first mentioned. In the experiments now particularly referred to, the two electrodes were made of the customary size, the hammer small, and the anvil large.

An inspection of the curves shows that the character of the result obtained under these circumstances was determined chiefly by the material of the anvil rather than of the hammer electrode. This is particularly well illustrated in the case of iron and carbon, as shown in Figures 6 and 7.

This difference persisted even when the hammer and anvil electrodes were made of the same size and shape, as will be seen by an inspection of Tables IX. to XVI., and Figures 9 to 14. We have still to determine whether the same peculiarity would be observed with other modes of mounting the electrodes.

Besides the foregoing results, we have made a determination of the actual strength of the working currents employed on telephone lines. The values previously obtained in the Laboratory had been ascertained from experiments on very short experimental circuits. But through the courtesy of the Long Distance Telephone Company, we were able to put our measuring apparatus in circuit both with the city telephone lines and with one of the long lines to New York.

Several interesting results were thus reached, as shown in Table

XVII. The first column gives the name of the transmitter employed, the second the nature of the sound transmitted, the third the location of the transmitter, the fourth the strength of the telephone current in milliampères. The length of the line from 95 Milk Street to the Institute was about two miles; that of the line to New York was two hundred and sixty miles.

TABLE XVII.

Transmitter.	Sound.	Locality of Transmitter.	Current.
Blake	Talking	95 Milk Street	.185
"	Singing	"	.52
Hunnings	Talking	"	.28
"	Singing	"	.78
"	Talking	New York	.02
"	Counting	"	.02 −
"	Organ Pipe	"	.01 +
"	Counting	Rogers Laboratory	2.05
"	Talking	"	2.20
"	Organ Pipe	"	1.24

The speakers were Dr. W. W. Jacques of Boston and Mr. F. A. Pickernell of New York, who kindly aided us in our work. They are both experts in the use of the telephone, and accustomed to work with each other. The pitch, as well as the loudness of the sounds used, was kept as nearly as possible the same. The vocal sounds transmitted were spoken in a very loud tone, and close to the transmitter.

The figures obtained with the long line to New York are very instructive, as they give some knowledge of the loss of current which is sustained in long distance telephony. When the transmitter was at the Institute, near to the dynamometer, the full current produced by the former passed through the latter instrument, while, when the transmitter in New York was the one used, it is clear that only what was left after all leakage, etc., passed through the measuring instrument. Assuming the sounds as produced at the two stations to be of approximately the same pitch and loudness, it appears that only about one one-hundredth of the original current produced at the transmitting station is finally utilized at the receiving station. It further appears from these figures that about 13 per cent of the current produced at the transmitting station was utilized in ordinary telephonic transmission over the local lines from 95 Milk Street to the Laboratory.

ROGERS LABORATORY OF PHYSICS,
June, 1888.

THE STRENGTH OF THE INDUCED CURRENT WITH A MAGNETO-TELEPHONE TRANSMITTER AS INFLUENCED BY THE STRENGTH OF THE MAGNET.

By CHARLES R. CROSS, S.B., and ARTHUR S. WILLIAMS, S.B.*

It is a well-known fact in practice, as well as an evident consequence of theoretical considerations, that the effectiveness of a magneto-telephone when used either as a transmitter or as a receiver varies with the strength of the magnetism of the core. But the relation of the one to the other has never been studied, so far as we are aware.

Our investigations include a study of the changes in strength of the current produced by a magneto-transmitter under varying conditions of magnetization, and of the magnitude of the momentary changes in the magnetic condition of the core of the receiving telephone when subjected to the action of undulatory or other brief currents, as influenced by the strength of the primitive permanent magnetization of the core. The present paper contains only the results of a series of experiments relating to the first of these, that is, to the effect of varying strength in the magnet of the transmitter; the study of the allied problem of the receiver being still in progress.

The apparatus employed consisted of a cylindrical bar of soft iron about $4\frac{1}{2}$ inches in length and $\frac{1}{4}$ of an inch in diameter, around one end of which was placed a coil of fine wire similar to that used in ordinary telephonic practice. The resistance of this coil was 100 ohms. It was placed in circuit with a ballistic mirror galvanometer, from whose deflection the momentary current produced in the coil by any variation in the strength of the core could be determined. The diaphragm, which was in all cases $2\frac{5}{16}$ inches in diameter, was in its usual place opposite the end of the magnet about which the wire coil was wound, and about $\frac{8}{100}$ of an inch from that end. By means of a rod carrying a cam moved by a weight, a rapid inward push of definite amount was given to the diaphragm, thereby inducing a current in the coil already referred to, and so deflecting the needle of the ballistic galvanometer. The soft iron bar was also surrounded by a second helix, through which was passed a current from a storage battery, serving to magnetize the core. A tan-

* Read at a meeting of the American Academy of Arts and Sciences, Nov. 14, 1888.

gent galvanometer inserted in this circuit gave the strength of the magnetizing current. A magnetometer placed in the prolongation of the axis of the core, which last occupied an east and west position, made known the relative strengths of the field produced by the core under different conditions of magnetization.

Corresponding observations of the magnetometer reading, and of the current induced when the diaphragm was moved by the cam, were made throughout a widely varying range of strength of field, and the results were represented graphically by constructing a series of curves in which ordinates represent the relative strength of field, and abscissas the current due to a given predetermined throw of the diaphragm (about $\frac{1}{100}$ of an inch), as ascertained from the readings of the ballistic galvanometer.

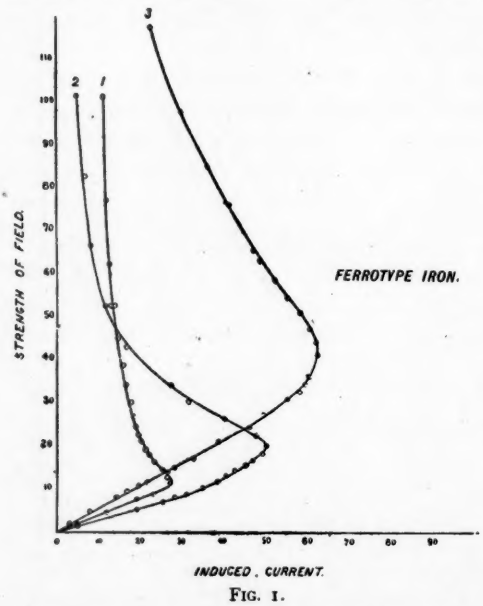

FIG. 1.

One of these curves is shown at 1, Figure 1, the core in this case being a cylindrical bar of Norway iron $4\frac{1}{5}$ inches long and $\frac{1}{4}$ of an inch in diameter, and the diaphragm an ordinary disk of ferrotype iron $2\frac{5}{16}$ inches in diameter and $\frac{1}{100}$ of an inch thick (No. 31 B. W. G.).

Table I. gives the data from which Figure 1 was constructed. The strength of field is given in terms of the tangents of the angles of deflection of the magnetometer needle. The induced current is given in arbitrary units, as only relative values are needed. A determination of the value of the deflections was made by observing the excursion due to the discharge of a condenser through the ballistic galvanometer, and it was found that the abscissa 100 on the curves corresponds to a sudden discharge of approximately 0.00000097 of a coulomb through the coils of the galvanometer.

TABLE I.

CORE, NORWAY IRON. — DIAPHRAGM, DISK OF FERROTYPE IRON, NO. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
...	0.7	.146	25.3	.302	18.0
.016	3.3	.164	23.8	.342	16.9
.044	12.0	.182	22.5	.390	16.1
.058	19.3	.196	21.6	.454	14.7
.089	23.3	.211	20.5	.530	13.3
.118	27.0	.229	19.8	.625	12.7
.141	26.8	.248	19.2	.773	12.0
.132	26.6	.270	18.7	1.014	11.5

Cores of Bessemer steel and of untempered soft steel were also used, with results given in Tables II. and III.

TABLE II.

CORE, BESSEMER STEEL. — DIAPHRAGM, DISK OF FERROTYPE IRON, NO. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.005	2.0	.213	19.3	.507	13.5
.030	7.7	.248	18.6	.625	11.7
.082	20.7	.279	17.8	.748	10.8
.137	26.7	.333	16.7	.907	9.7
.160	24.8	.396	15.0	1.099	8.7
.191	21.2				

TABLE III.

CORE, UNTEMPERED SOFT STEEL. — DIAPHRAGM, DISK OF FERROTYPE IRON, NO. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.031	8.2	.171	22.9	.388	15.2
.049	12.0	.194	21.1	.473	13.8
.089	22.0	.216	19.7	.618	12.7
.137	25.9	.275	18.0	.776	11.0
.157	24.9	.321	16.5	1.011	9.5

An examination of Figure 1, as well as of the various curves following it, will show that the effect of increasing the strength of the magnet of the transmitter is in all cases to cause at first a rather rapid increase of the strength of the induced current, which later increases less rapidly, rising soon to a maximum value, from which it falls off, at first rapidly, and afterwards more and more slowly as the strength of the field is further increased. We proceed to consider the explanation of these results.

It is evident that three distinct sources of variation exist to affect

the current furnished by a magneto-transmitter as the strength of the magnet is increased. First, the direct effect of the increased strength of field in which the diaphragm moves is to increase proportionally the strength of the induced current, since it increases correspondingly the rate of change in the number of lines of force enclosed by the coil of the instrument; second, an approach toward saturation of the magnet so far as it alone is concerned, will tend to diminish the induced current on account of the smaller variation in the strength of the pole due to a given motion of the diaphragm; and, third, the nearer approach toward saturation of the diaphragm will have the same tendency.

The rapid rise in the induced current at the beginning is of course due to the predominating influence of the increasing strength of the field in which the diaphragm moves, as both core and diaphragm are then but slightly magnetized. The subsequent changes in the current must be explained by a consideration of the increasing magnetization of either the core or the diaphragm, or both.

It will be seen by comparing Tables I., II., and III., that the value of the maximum induced current for a given excursion of the diaphragm is approximately the same with all the three cores used, and that the same is true as to the strength of field corresponding to this maximum current. Moreover, saturation curves constructed for the several cores showed that in all cases the magnet was still very far removed even from half-saturation when the maximum induced current was obtained. From these facts it appears that the degree of saturation of the magnet is practically unimportant, so far as the general results shown in Figure 1 are concerned.

It remains to observe the part played by the increasing magnetization of the diaphragm. Other things remaining the same, as this approaches more and more closely towards saturation the increase in the number of lines of force passing between it and the magnet on the approach of the diaphragm to the magnet must become smaller and smaller, and this change will tend to oppose the effect of the increased absolute strength of the magnetizing force. The small mass of the diaphragm will evidently cause it to show the effect of an approach to saturation while the core is far below that condition. And such an action will clearly explain the observed changes in the current strength.

In order to test this matter still further, the experiment was tried of varying the mass and material of the diaphragm.

The results are shown by the curves in Figures 1, 2, and 3, which are constructed from the data given in Tables I. to X.; further results of the same character are given in Tables XI. and XII.

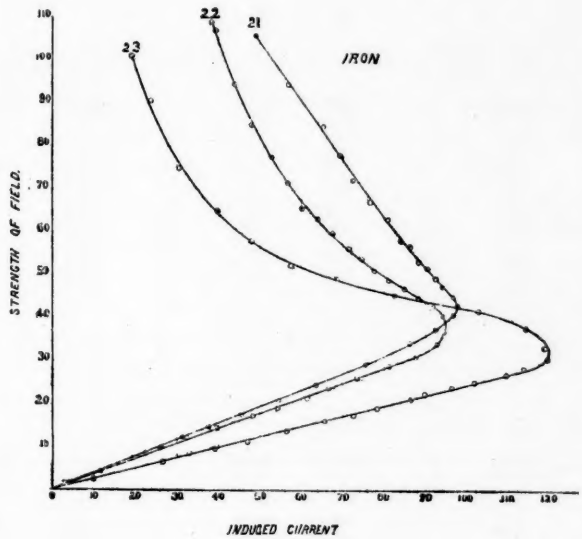
22
21
23
IRON
STRENGTH OF FIELD.
INDUCED CURRENT

FIG. 2.

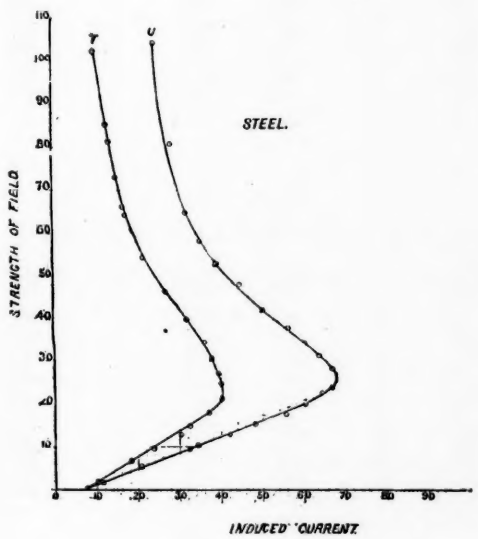
T
U
STEEL.
STRENGTH OF FIELD
INDUCED CURRENT

FIG. 3.

TABLE IV.

CORE, NORWAY IRON. — DIAPHRAGM, TWO SUPERPOSED DISKS OF FERROTYPE IRON, NO. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.016	5.0	.144	42.7	.306	31.8
.054	19.3	.155	45.7	.342	27.7
.070	25.7	.169	47.0	.433	16.7
.081	28.5	.184	49.3	.530	11.9
.089	30.2	.205	50.2	.667	8.3
.103	35.0	.229	48.0	.830	7.0
.119	38.5	.266	40.3	1.018	5.0
.133	40.7				

TABLE V.

CORE, NORWAY IRON. — DIAPHRAGM, THREE SUPERPOSED DISKS OF FERROTYPE IRON, NO. 31.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.000	0.5	.213	39.0	.479	61.0
.018	3.2	.249	46.3	.514	58.5
.047	8.0	.277	49.8	.550	55.7
.079	14.2	.313	55.3	.591	52.4
.084	14.7	.329	58.7	.637	48.7
.096	17.0	.346	59.7	.659	47.3
.110	19.7	.366	60.7	.765	41.7
.118	21.8	.390	61.3	.854	36.7
.135	25.5	.416	63.0	.983	30.0
.151	28.3	.445	62.3	1.180	22.8
.175	33.0				

TABLE VI.

CORE, NORWAY IRON. — DIAPHRAGM, SHEET IRON, NO. 21.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
. . .	0.3	.296	75.5	.573	86.7
.016	3.1	.348	86.2	.584	84.0
.058	13.7	.378	92.3	.637	81.0
.082	20.3	.416	96.7	.675	76.7
.102	25.2	.437	97.8	.724	72.3
.125	31.2	.456	96.7	.784	69.3
.150	37.8	.477	94.0	.851	65.6
.178	45.5	.499	92.5	.949	57.3
.213	54.7	.521	90.5	1.061	49.1
.249	63.8	.536	88.3		

Table VII.

Core, Norway Iron. — Diaphragm, Sheet Iron, No. 22.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
...	1.7	.262	73.2	.541	74.7
.018	4.7	.292	81.3	.566	71.3
.047	11.7	.313	87.7	.601	67.7
.075	19.7	.342	92.7	.635	64.0
.088	22.3	.372	94.3	.659	60.0
.100	26.0	.410	94.2	.719	56.7
.123	32.5	.431	92.0	.779	53.0
.146	39.5	.452	88.3	.851	48.0
.171	48.2	.473	85.0	.946	44.0
.194	54.2	.494	81.2	1.072	39.3
.218	61.3	.516	77.5	1.091	38.3
.240	66.9				

Table VIII.

Core, Norway Iron. — Diaphragm, Sheet Iron, No. 23.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
...	1.7	.216	86.4	.420	102.9
.026	10.0	.229	90.0	.458	82.2
.068	26.8	.242	96.3	.499	68.7
.086	33.0	.255	101.8	.529	57.6
.096	39.0	.272	109.3	.582	48.0
.116	47.0	.289	113.8	.652	39.9
.139	56.3	.310	119.3	.751	30.8
.162	65.8	.339	118.6	.904	23.7
.176	72.3	.382	114.1	1.011	19.0
.194	78.3				

Table IX.

Core, Norway Iron. — Diaphragm, Steel, No. 26, Untempered.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.004	7.7	.200	60.3	.422	50.5
.019	11.5	.227	64.3	.483	44.7
.054	20.5	.236	67.0	.530	39.0
.095	32.2	.281	66.7	.584	35.3
.105	34.5	.313	63.8	.652	32.0
.128	42.0	.342	60.4	.810	28.2
.153	48.3	.380	56.3	1.043	24.3
.178	55.7				

TABLE X.

CORE, NORWAY IRON. — DIAPHRAGM, STEEL, NO. 26, TEMPERED.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.002	7.8	.214	40.2	.545	21.7
.019	10.4	.246	40.0	.642	17.7
.068	18.5	.272	39.5	.662	17.3
.096	23.8	.304	37.9	.732	15.2
.128	30.3	.344	36.3	.816	13.8
.151	32.4	.400	32.0	.854	13.0
.180	37.0	.466	26.9	1.025	10.0

TABLE XI.

CORE, NORWAY IRON. — DIAPHRAGM, STEEL, NO. 22, UNTEMPERED.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.007	6.2	.176	35.0	.392	29.7
.023	8.0	.202	37.1	.458	26.3
.070	17.3	.224	34.9	.538	23.2
.103	23.0	.246	37.0	.566	23.0
.121	26.4	.272	36.7	.647	21.7
.139	30.1	.302	34.8	.773	19.8
.157	32.8	.340	33.0	1.046	17.6

TABLE XII.

CORE, NORWAY IRON. — DIAPHRAGM, STEEL, NO. 30, TEMPERED.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.007	6.2	.176	35.0	.392	29.7
.023	8.0	.202	37.1	.458	26.3
.070	17.3	.224	. . .	.538	23.2
.103	23.0	.246	37.0	.566	23.0
.121	26.4	.272	36.7	.647	21.7
.139	30.1	.302	34.8	.773	19.8
.157	32.8	.340	33.0	1.046	17.6

TABLE XIII.

CORE, NORWAY IRON. — DIAPHRAGM, STEEL, NO. 30, UNTEMPERED.

Strength of Field.	Induced Current.	Strength of Field.	Induced Current.	Strength of Field.	Induced Current.
.005	5.2	.200	38.3	.512	23.3
.031	11.7	.231	36.2	.632	20.4
.082	24.2	.272	35.2	.735	19.7
.103	29.7	.331	31.2	.819	18.0
.130	37.7	.376	28.9	.956	16.3
.160	41.9	.437	26.0		

Curve 2, Figure 1, represents the results when two of the ordinary ferrotype diaphragms were superposed, forming a diaphragm of double thickness, and Curve 3 of the same figure shows the results when three such diaphragms were superposed. Each diaphragm was 0.01 of an inch thick. The curves of Figure 2, marked 21, 22, 23, respectively, show the results of similar experiments with diaphragms of sheet iron whose thickness was 0.030, 0.027, 0.024 of an inch, respectively (Nos. 21, 22, 23, B. W. G.). Figure 3 shows the results when a steel diaphragm 0.017 of an inch thick (No. 26) was used, the curve *U* being that for untempered steel, and *T* that for tempered steel. Steel diaphragms respectively 0.026 and 0.012 of an inch thick (Nos. 22 and 30) gave similar results, as will be seen from Tables XI., XII., and XIII.

An inspection of these curves shows immediately that the greater the strength of the field required to saturate the diaphragm, the greater is the strength of the field at which the maximum current occurs. Thus in Figure 1 the maximum current with Curve 1 corresponds to a strength of field of about 12 units of the scale used, while with Curves 2 and 3 the corresponding strengths of field are 20 and 43 units respectively. Also in Figure 2 the maximum currents will be seen to correspond to greater strengths of field in proportion to the thickness of the diaphragm, and in Figure 3 similar though less marked results hold for tempered as compared with untempered steel of the same thickness.

It would also be expected that the value of the maximum current would be greater with a thick than with a thin diaphragm. This was usually the case in our experiments. Thus the Curves 1, 2, 3, of Figure 1 give maximum currents of 27.5, 50.2, and 62.6 units respectively. Results of a similar nature are shown by Figure 3, the maximum current with the untempered diaphragm being far greater than with the tempered one. Curve No. 23 of Figure 2 is apparently an exception. It is probable, however, that this is in appearance only, and that the three curves of that figure are not strictly comparable with one another. The rigidity of the diaphragms here used, especially of the thicker ones, is considerable, and any slight yielding of the supports of the rod which carried the cam would prevent the actual throw of the diaphragm from being as great when this had considerable thickness, and would greatly diminish the strength of the current produced.

The peculiarity of Curve 2 as compared with 1 and 3 is probably caused by the want of both magnetic and mechanical continuity in the material of the multiple plate formed by the several diaphragms used.

In those cases where steel diaphragms were employed, there was always a notable induced current, even when the reading of the mage-

tometer was zero. This was probably due to a slight residual magnetization of the diaphragms.

The results stated in this paper may serve to explain a phenomenon which has seemed somewhat obscure. Frequent attempts have been made to increase the efficiency of a magneto-transmitter by polarizing the diaphragm as well as the magnet, a common way of doing this being to employ a horseshoe magnet one leg of which is in contact with the edge of the diaphragm, while the other, about which the coil is wound, is placed in its usual position opposite the centre. But as a general rule little or no gain has seemed to result therefrom, so far as can be judged by the performance of such instruments in actual practice. It is quite probable in this case that the increased approach to saturation of the diaphragm may have so great an effect as entirely to prevent the expected improvement.

It will also be seen from our results, that an increase in the thickness of the diaphragm of a magneto-transmitter tends to allow of the use of a stronger magnet, and for a given amplitude of vibration to produce a stronger current. But it must be remembered, on the other hand, that the greater rigidity of the thick diaphragm will diminish this range of vibration under the action of the voice, a difficulty which may to a certain extent be remedied by using a diaphragm of large diameter.

ROGERS LABORATORY OF PHYSICS,
October, 1888.

NOTE ON THE EFFICIENCY OF SMALL ELECTRO-MOTORS.

H. E. H. CLIFFORD, S.B.

Some results of efficiency tests on small motors, which I published in the Technology Quarterly for September, 1887, have been very unfavorably criticised by Professors Ayrton and Perry in the *Philosophical Magazine* for July, 1888. Through an apparent misunderstanding of my tables, they assert that the motors were not run at the potential differences and currents for which they were wound, and hence that the results "are not only valueless, but are most misleading."

Undoubtedly, their mistake arises from accepting the potential differences and currents given in Table I. as the maximum values, or nearly so, at which the motors were run. A glance at Table II. will show, however, that in the typical series especially selected for illustration of the effect of varying speed, the number of watts supplied to the motor was largely in excess of the number for maximum efficiency, while a comparison of Tables I. and III. shows that so far as the output of the motors is concerned, the experiments were by no means confined to a limited range.

At the time the tests were carried on, very little information could be obtained as to the proper conditions under which most of the motors tested (including the Ayrton and Perry motor) were to be run. Consequently a large range of potential differences and currents was used, the speed also being varied between wide limits. In the case of the Model Edison Dynamo, which was selected as illustrating the relation of speed and efficiency, and which was known to be wound for 100 volts and 0.8 of an ampère, the range of C, E.M.F. and speed was not so great as with the other machines tested. Professors Ayrton and Perry base their assertion on the results of the tests upon their own motor, which, they state, was supplied with less than one-quarter of the power at which it was intended to run.

The facts of the case are that the Ayrton and Perry motor used was the one tested at the International Electrical Exhibition of the Franklin Institute at Philadelphia, in 1884, where, with a speed of 1500 revolutions a minute, an efficiency of 28.5 per cent was obtained as against an efficiency of 38.4 per cent with a speed of 831 revolutions a minute found by us.

In our tests it was supplied with as many as 400 watts and run at as great a speed as 1700 revolutions per minute. It is possible that the Ayrton and Perry motor of the type tested was designed to utilize four times the power at which it was found to give its maximum efficiency, but it is certain that the especial motor tested could not by any possibility have been run under such conditions in practice, or indeed run continuously for more than a few minutes, without rapidly destroying it, since intolerable heating of the armature and most damaging sparking at the commutator would have resulted. The conditions for maximum efficiency which we found, however, were those given in Table I., and the maximum output is that given in Table III.

It is of course understood that in the tests the motors were not habitually run with heating of the machine, or sparking at the commutator, greater than would be compatible with practical use; but in every case the motor was tested for maximum output.

Bearing the facts stated in mind, it is clear that the range of the tests was in every case great enough to include the proper conditions for the individual motor tested.

The results given in my article are wholly those obtained by students, and are unquestionably subject to the defects incident to such work, but they are nevertheless trustworthy within the limits claimed, and I think also of some interest in view of the great paucity of published results relating to motors of the class under discussion.

ON THE DETERMINATION OF THE ORGANIC NITROGEN IN NATURAL WATERS BY THE KJELDAHL METHOD.

By THOMAS M. DROWN, M.D., and HENRY MARTIN, S.B.

The justification for the almost universal practice of determining the organic nitrogen in waters in the form of albuminoid ammonia is to be found in the great simplicity of the Wanklyn process. The amount of nitrogen obtained in the form of ammonia by the action of alkaline permanganate on nitrogenous organic matter in water bears no known relation to the total nitrogen present, and chemists report widely differing results in consequence of differing practice. In the case of colorless waters, with small amount of organic matter, the differences are not usually great, but in most surface waters, with considerable organic matter in suspension and solution, the results often differ fifty or one hundred per cent. Some water analysts stop the distillation for albuminoid ammonia when 150 c.c. have distilled over; others continue until 250 c.c. are obtained, and again, others strive to get all the ammonia they can by the addition of more alkaline permanganate, or by replacing the water which has distilled over.

There can be no doubt that the determination of the total organic nitrogen would be generally practised in place of the determination of the albuminoid ammonia, if there was available a short, easily executed, and accurate method for this purpose.

As the result of a very large number of experiments with the Kjeldahl nitrogen process, we think it may be safely said, that this method leaves little, if anything, to be desired in these respects.

The modifications of the process, as usually practised, to adapt it to the determination of organic nitrogen in waters, are in the direction of its simplification. Thus, the amount of organic matter in water is ordinarily so very small that the use of solid potassium permanganate for the final and complete oxidation of the organic matter is probably never necessary. In most of the analyses which we have made, we have continued to use it as a matter of precaution, but in the comparative experiments, with and without its use, the results have not differed. The volumetric determination of the ammonia by titration with very dilute standard acid was found to be less accurate and less convenient

than the Nesslerization of the distillate, in the usual method employed in water analysis. Further, the same flask is used for both the digestion and the distillation.

Professor W. R. Nichols experimented with the Kjeldahl process for the determination of the nitrogen in sewage with satisfactory results,* but the process has not yet, far as we know, been used in regular water analysis.

The examination is conducted as follows: 500 c.c. of the water is poured into a round-bottom flask, of about 900 c.c. capacity, and boiled until 200 c.c. have been distilled off. The "free ammonia" which is thus expelled may, if desired, be determined by connecting the flask with a condenser. To the remaining water in the flask is added, after cooling, 10 c.c. of pure concentrated sulphuric acid.† After shaking, the flask is placed in an inclined position on wire gauze, on a ring-stand, or other convenient support, and boiled cautiously, in a good-drawing hood, until all the water is driven off and the concentrated sulphuric acid is white or a very pale yellow. The flask is then removed from the flame, and a very little powdered potassium permanganate added until, on shaking, the liquid acquires a green color, showing that an excess of the permanganate has been added. Should the color be purple instead of green, it shows that the water has not all been driven off. After cooling, 200 c.c. of water free from ammonia are added, the neck of the flask being washed free from acid, and then 100 c.c. of sodium hydrate‡ solution. The flask is immediately connected with the condenser, and then shaken to mix the contents.

The distillation at the start is conducted rather slowly, and the first 50 c.c. are condensed in very dilute hydrochloric acid.§ The contents of the flask may then be boiled more rapidly until 150 c.c. to 175 c.c. have altogether been collected. The total distillate is made up to 250 c.c. with water free from ammonia, well mixed, and 50 c.c. taken for Nesslerization. No serious difficulty has been encountered from bumping when boiling the alkaline solution. The use of metallic zinc in the

* Franklin Institute Journal, August, 1885.

† It is necessary to have for this purpose sulphuric acid which is very nearly, if not quite, free from nitrogen in any form. Baker & Adamson, of Easton, Penn., make an acid for this purpose which contains only .05 milligram of ammonia in 10 c.c.

‡ The sodium hydrate solution is made by dissolving 200 grams of commercial caustic soda of good quality in 1.25 litres of distilled water, adding two grams of potassium permanganate and boiling down to somewhat less than a litre. When cold, the solution is made up to a litre. The addition of the permanganate is to oxidize any organic matter which may be present in the caustic soda.

§ This acid should be free from ammonia: 1 c.c. of the acid is equivalent to 0.5 milligram of ammonia.

flask to facilitate the boiling is, of course, inadmissible, on account of the reduction of nitrates and nitrites, should they be present, to ammonia.

Any efficient condensing arrangement may be used for the collection of the ammonia. We have used with great satisfaction the condenser devised by Prof. S. W. Johnson, of the Connecticut Agricultural Experiment Station, which is described in Bulletin No. 12, of the United States Department of Agriculture, Division of Chemistry. It consists of a copper tank, 20 inches high, 32 inches long, 3 inches across the bottom, widening to 6 inches at the top. The tank is provided with an adequate supply of running water, entering at the bottom, and accommodates 6 or 7 block-tin condensing-tubes three-eighth inch internal diameter, which enter the tank through holes in the front side near the top, above the level of the overflow, and pass down vertically through the tank and out through rubber stoppers tightly fitted into holes in the bottom. They project about 2 inches below the tank, and are connected by means of rubber tubes to straight glass calcium-chloride tubes with a bulb at the upper end. These glass tubes dip into 250 c.c. flasks which receive the distillate. The distilling-flasks are connected with the tin condensing-tubes, by means of rubber stoppers which carry a bulbed-glass tube bent at right angles. This tube and its rubber stopper remain permanently connected with the tin tube.

The flasks rest on iron rings, and are heated with the free flame of a Bunsen burner. They should be carefully selected as to size and height, and the fixtures should be so arranged that all parts are interchangeable. There is then never any difficulty in putting the flasks promptly into place and connecting them with the condenser.

It is a good plan to have flasks, partly filled with water free from ammonia, connected with the condensing-tubes when not in use.

Before beginning a determination, the water in the flask is boiled until the distillate shows, on Nesslerization, that the apparatus is completely free from ammonia. Into the flask which receives the distillate there is put 1 c.c. of the dilute hydrochloric acid and 50 c.c. of water. The delivery tube dips into this liquid only during the collection of the first 50 c.c. of the distillate. The flask is then lowered so that the tube remains above the liquid for the remaining time of the distillation.

In carrying out the operation, the most scrupulous care must be observed in preventing access of ammonia from any source. The acid solutions will absorb ammonia from the air of the laboratory or from the dust of the room if they are allowed to remain uncovered for any length of time. This source of error has been found at times to be very large;

quite enough to render a determination valueless. One experiment gave a gain of ammonia in twenty hours, by leaving the flask which contained the concentrated sulphuric acid uncovered, equivalent 0.5 c.c. of the standard ammonium chloride solution, and at another time the gain was 3 c.c.

The operation should, therefore, be carried out without interruption, and for every determination, or set of determinations, a blank analysis with ammonia-free water should be made for a correction for the ammonia in the reagents and that accidentally introduced in the process.

We have not found that the presence of nitrates and nitrites in waters interferes with the accurate determination of the organic nitrogen. The error which has been found by Kjeldahl and Warrington * to be caused by nitrates in the determination of organic nitrogen seems to disappear under the conditions of great dilution which we have in natural waters.

The following experiments bear on this point: —

1500 c.c. standard ammonium chloride solution (= 15 milligrams NH_3) and 10 c.c. of standard potassium nitrite solution (= 1 milligram N) were boiled with 10 c.c. of sulphuric acid, and the vapors condensed. This distillate contained only 0.15 milligram nitrogen as ammonia and nitrous acid. The residue in the flask was made alkaline and distilled, and the ammonia obtained was precisely the amount taken; namely, 1500 c.c. The experiment was repeated, using a nitrate in place of the nitrite, and under the same conditions the 1500 c.c. of ammonia were recovered.

When a smaller amount of ammonia was used, we still failed to observe any loss. Thus when 10 c.c. standard ammonium chloride solution and 10 c.c. potassium nitrite solution (= 0.1 milligram N) were treated as above, there was obtained ammonia equivalent to 10.5 c.c. Another experiment with the same quantities gave precisely 10 c.c. of ammonia regained. With potassium nitrate instead of nitrite, in the same proportions as in the foregoing experiment, 10.5 c.c. of ammonia were obtained.

The attempt to collect all the nitrous and nitric acids in the distillate was unsuccessful. The flask and condenser were connected by ground joints, so that the distillation could be continued after the sulphuric was concentrated. Owing, probably, to the shape of the flask, the acids were condensed, in part, in the neck of the flask, for after a second and a third addition of water and a renewal of the distillation more nitrous and nitric acids were obtained in the distillate. To see whether there

* Chemical News, 52, p. 162.

was any loss of ammonia from ammonium sulphate in presence of sulphurous acid from the action of sulphuric acid on carbonaceous matter, the following experiments were tried: 10 c.c. of standard ammonium chloride solution were treated with 10 c.c. of sulphuric acid and a weighed amount of Swedish filter paper. Deducting for the nitrogen in the paper, determined in a blank analysis, 10.5 c.c. of ammonia were obtained. In a duplicate experiment the ammonia obtained was 10 c.c.,—precisely the amount taken. In still another experiment with 50 c.c. of standard ammonium chloride solution and filter paper, 51 c.c. were obtained.

No attempt has been made to compare, as regard the results obtained, the above-described method of determining the organic nitrogen with the combustion method of Frankland and Armstrong. But the following experiments on very dilute solutions of organic substances of known composition may serve to confirm the accuracy of the method.

One hundred milligrams of pure crystals of urea were dissolved in one litre of water free from ammonia. Ten cubic centimetres of this solution were added to 500 c.c. of water and the analysis conducted as above described. There was obtained 0.494 milligram, the theoretical amount being 0.466. In a duplicate experiment no solid potassium permanganate was added to complete the oxidation, and the result was 0.486 milligram.

A solution of uric acid in dilute potassium hydrate was made of the same strength as the urea, and 10 c.c. taken for analysis. There was found 0.326 milligram of nitrogen; required, 0.333 milligram. In a duplicate experiment without the permanganate — precisely the same amount was obtained.

A solution of naphthylamine, 100 milligrams to the litre, was dissolved by the aid of dilute hydrochloric acid. An analysis of 10 c.c. gave 0.082 milligram nitrogen; required, 0.097. Here, again, the result obtained by the omission of the permanganate agreed precisely with the determination in which the permanganate was used.

The following series of experiments made on a sample of Cochituate water shows the very close agreement of results in the determination of organic nitrogen under varying conditions. From a large bottle of water freshly drawn from the tap, were taken five portions of 500 c.c. each.

The first portion was treated by the usual method, already described.

The second portion was treated like the first, except that the addition of solid permanganate was omitted.

The third portion received 10 c.c. of standard potassium nitrate solution, equivalent to 0.1 milligram of nitrogen.

The fourth portion received 1 c.c. of potassium nitrite solution, equivalent to 0.01 milligram of nitrogen.

The fifth portion contained ten times the amount of potassium nitrite as the fourth portion, or 0.1 milligram.

The third, fourth, and fifth portions were treated in all respects like the first portion.

The results, expressed in organic nitrogen, parts per 100,000, were: —

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
0.0354	0.0354	0.0354	0.0365	0.0365

It may be of interest to give a few of the results obtained in the determination of the organic nitrogen by this method in natural waters in comparison with the results obtained as albuminoid ammonia. In the table following will be found the analyses of some Massachusetts waters during three successive months, June, July, and August, 1888.

In the first column is a record of the color, based on a comparison with the Nesslerization of a known amount of ammonium chloride. Thus a color 1, means that the water possessed a color corresponding in depth and tint to 1 c.c. of standard ammonium chloride solution (=.00001 gr. NH_3) when Nesslerized; a color of 2 is twice the depth of color, and 0.1 is one-tenth the color of 1. In the second column is the albuminoid ammonia obtained by the adding 40 c.c. of alkaline permanganate to the water in the flask, after boiling off 150 c.c. for free ammonia, and then distilling over 250 c.c. In the third column is the organic nitrogen determined by the Kjeldahl process, converted into ammonia to make the figures comparable with the second column. All the determinations were made on the waters filtered through paper in the laboratory.

Comparison of Albuminoid Ammonia and Organic Nitrogen in Natural Waters.

I. Surface Waters.

Water.	Color.	Albuminoid Ammonia.	Organic Nitrogen calculated as Ammonia.
Arlington, Reservoir —			
June	.8	.0256	.0560
July	.3	.0274	.0560
Boston Supply, Basin 4 —			
June	1.0	.0226	.0470
July	.7	.0234	.0400
August	.9	.0254	.0460
Boston Supply, Basin 2 —			
June	1.4	.0350	.0590
July	1.3	.0294	.0450
August	.85	.0234	.0440
Boston Supply, Basin 3 —			
June	1.9	.0392	.0790
July	1.7	.0336	.0540
August	.8	.0278	.0590
Boston Supply, Lake Cochituate —			
June	.35	.0176	.0420
July	.10	.0192	.0390
August	.10	.0196	.0420
Boston Supply, Mystic Lake —			
June	.20	.0252	.0590
July	.10	.0244	.0560
August	.15	.0212	.0420
Bridgewater, Taunton River —			
June	2.3	.0248	.0520
July	1.0	.0210	.0440
August	.7	.0212	.0390
Brockton, Reservoir —			
June	.9	.0234	.0570
July	.9	.0260	.0490
August	.7	.0310	.0610
Brookline, Charles River —			
June	1.20	.0320	.0520
July	.60	.0216	.0470
August	.45	.0208	.0380
Cambridge, Fresh Pond —			
June	.20	.0162	.0370
July	.15	.0170	.0390
August	.0	.0172	.0390
Clinton, Nashua River —			
June	.1	.0072	.0230
July	.2	.0144	.0360
August	.2	.0124	.0320
Fitchburg, Reservoir —			
June	.1	.0124	.0250
July	.1	.0158	.0340
August	.1	.0146	.0240
Great Barrington, Housatonic River —			
June	.1	.0122	.0320
July	.1	.0120	.0270
August	.0	.0134	.0320
Nashua, Merrimac River —			
June	.4	.0120	.0320
July	.2	.0132	.0290
August	.2	.0106	.0290
Lowell, Merrimac River —			
June	.30	.0142	.0420
July	.10	.0148	.0280
August	.25	.0134	.0320
Haverhill, Merrimac River —			
June	.40	.0164	.0490
July	.20	.0170	.0420
August	.20	.0163	.0348
Lake Winnepesaukee —			
June	.0	.0090	.0230
July	.0	.0082	.0190
August	.0	.0080	.0200
Hyde Park, Neponset River —			
June	.6	.0286	.0520
July	.8	.0432	.1100
Lynn, Birch Pond —			
June	.45	.0194	.0420
July	.35	.0216	.0410
August	.25	.0174	.0410
Malden, Spot Pond —			
June	.3	.0216	.0440
July	.2	.0198	.0390
August	.2	.0216	.0390

Water.	Color.	Albuminoid Ammonia.	Organic Nitrogen calculated as Ammonia.
Montague, Connecticut River —			
June	.15	.0120	.0220
July	.20	.0118	.0250
Springfield, Connecticut River —			
June	.4	.0132	.0390
July	.15	.0146	.0320
August	.15	.0170	.0380
New Bedford, Acushnet River —			
June	2.3	.0296	.0540
July	1.8	.0278	.0540
Northboro, Assabet River —			
June	.7	.0192	.0490
July	.4	.0216	.0380
August	.4	.0174	.0410
Salem, Wenham Lake —			
June	.10	.0132	.0320
July	.05	.0118	.0290
August	.00	.0130	.0260
Springfield, Ludlow Reservoir —			
June	.10	.0222	.0460
	.20	.0214	.0440
July	.10	.0220	.0420
August	.05	.0198	.0390
	.10	.0206	.0370
Wayland, Reservoir —			
June	1.5	.0272	.0590
July	.9	.0364	.0660
August	.4	.0244	.0540
Whitman, Hobart's Pond —			
June	1.7	.0538	.0990
July	1.5	.0426	.0990
August	.9	.0342	.0740
Wilmington, Shawsheen River —			
June	.8	.0242	.0640
July	.15	.0114	.0370
August	1.00	.0316	.0570
Woburn, Horn Pond —			
June	.35	.0290	.0570
July	.25	.0324	.0590
August	.10	.0240	.0440
Worcester, Blackstone River —			
June	—	.0350	.1350
July	—	.0440	.1550
August	—	.0830	.3800

II. GROUND WATERS.

(*Without Color.*)

Water.	Albuminoid Ammonia.	Organic Nitrogen as Ammonia.
Brookline, Filter Gallery —		
June	.0046	.0190
July	.0046	.0220
August	.0042	.0170
Newton, Filter Gallery —		
June	.0044	.0190
July	.0072	.0160
August	.0052	.0100
Revere, Wells —		
June	.0018	.0034
July	.0034	.0070
August	.0018	.0100
Revere, Reservoir —		
June	.0034	.0130
July	.0046	.0150
August	.0060	.0190
Waltham, Filter Gallery —		
June	.0030	.0170
July	.0050	.0160
August	.0056	.0150
Waltham, Reservoir —		
June	.0042	.0230
July	.0042	.0180
August	.0060	.0160

It will be noted that the organic nitrogen in the surface waters is in general about double the albuminoid ammonia. The average of all the analyses of the waters given above is 0.0214 for the albuminoid

ammonia, and 0.0476 for the organic nitrogen. In the ground waters the relation of the albuminoid ammonia to the organic nitrogen is still less. Too much importance must not, however, be given to this relation in the case of the ground waters, for it is probable that the figures given for the organic nitrogen are all a little high, owing to the fact that all of the sources of error were not fully known when most of the analyses were made. The proportional excess in case of the surface waters is believed to be insignificant, but with the smaller content of nitrogen in the ground waters the error is perhaps proportionately large.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
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THE NARROW GAUGE RAILWAY VERSUS *THE STANDARD GAUGE.**

BY STEJIRO FUKUZAWA.

DURING the early stage of railway operations in England, a great controversy arose among engineers as to the best gauge to be adopted for railways. Accustomed to the old tramway gauge of 4 feet 8½ inches, George Stephenson believed that it "was most economical in construction, not only as regarded the engines and carriages, but more particularly of the railway itself." Accordingly it was adopted on the Stockton and Darlington Railway, and most of the other early railways of England. But since this gauge was not the result of technical investigations, but originated, as is well known, entirely by chance, it was natural that many engineers were not satisfied with it. They thought that it was too narrow, and advocated gauges of 5 feet, 5 feet 3 inches, and 7 feet. These broader gauges were adopted on several railways, including the Great Western, which was built with a gauge of 7 feet. But a great majority of the railways were built with the original gauge of 4 feet 8½ inches. The contest of the gauges continued for several years. At last, in 1846, it was practically settled by the passage of an act fixing the gauge of 4 feet 8½ inches on all the railways in England and Scotland, except the Great Western Railway. Thus, in spite of the severe opposition of many engineers, 4 feet 8½ inches became the standard gauge of England, while in Ireland, 5 feet 3 inches was adopted as the standard. In the United States and Canada, also, several railways were built at first with broad gauges; but most of them were subsequently relaid to the standard gauge of 4 feet 8½ inches. The same was true in most of the continental countries in Europe; and thus the gauge of 4 feet 8½ inches became the all but universal gauge of the railway.

The failure of the broader gauges led to the opposite extreme. It was reasoned that because broader gauges were less economical than the standard gauge, therefore narrower gauges must be more economical than the standard. In 1870 Robert F. Fairlie read a paper before the British Association, at Liverpool, in which he strongly condemned

* A graduating thesis in the department of civil engineering, May, 1888.

what he considered the needless extravagance of the standard gauge, and most emphatically assured great economy in both construction and operation, that would result from the adoption of narrower gauges, ranging from about 3 feet 6 inches down to about 2 feet 6 inches. He said: —

"Every inch added to the width of a gauge beyond what is absolutely necessary for the traffic, adds to the cost of construction, increases the proportion of dead weight, increases the cost of working, and in consequence increases the tariffs to the public, and by so much reduces the useful effect of the railway." He undertook to show that if the gauge of the London and North-Western Railway had been 3 feet instead of 4 feet 8½ inches, its goods traffic could have been hauled at half the then existing cost.

At the time when Fairlie read his paper, all the railway companies in Great Britain were in a very poor financial condition, most of them paying small dividends or none at all. Fairlie attributed this fact to the unnecessary width of the standard gauge; and he did not have much trouble in making the public agree with him on this point. The narrow gauge mania spread quickly over all England. Nor were other countries in Europe and America wanting in enthusiastic followers of "the narrow gauge apostle." In Belgium, France, Italy, Switzerland, Russia, Norway, Austria, and Germany, narrow gauge railways were built more or less extensively. In India, the metre gauge was adopted by the government. In the United States, the first line of narrow gauge railway ever built, was the Denver and Rio Grande, opened to traffic in 1871. Narrow gauge advocates in the United States, like those in all other countries, were extremely enthusiastic, claiming all sorts of advantages for the narrow gauge; and many were sure that the 3-feet gauge would become the standard gauge in the future.

But they were greatly mistaken on that point; for in none of the countries in the world that have a large railway mileage, has the length of narrow gauge railways ever become more than a small per cent of the total length of railways. In the following table it will be seen that in this country narrow gauge railways constituted in 1886 only 9.2 per cent of the total mileage. Since that time several large narrow gauge lines have been relaid to the standard gauge, so that at present the percentage is, in all probability, considerably less than 9.2 per cent. Besides this, 9.2 per cent represents simply mileage. If we take into account the amount of traffic that passes over the lines, we shall certainly find that the business done by the narrow gauge railways is but a very small portion — much less than 9.2 per cent — of the total busi-

ness done by all the railways; since nearly all the narrow gauge railways in America are short secondary lines with but small traffic.

TABLE SHOWING MILEAGE OF NARROW GAUGE RAILWAYS IN THE UNITED STATES AT DIFFERENT PERIODS.

YEARS.	Mileage of Narrow Gauge Railways.	Total Mileage of Railways.	Percentage of Narrow Gauge to Total Mileage.
Beginning 1871	0	0	0
" 1872	179	60,951	0.3
" 1873	629	68,291	0.9
" 1874	1,184	72,174	1.6
" 1875	2,003	74,199	2.7
" 1876	2,588	75,760	3.4
" 1878	3,082	80,419	3.8
" 1880	5,605	87,801	6.4
" 1884	10,772	121,382	8.9
" 1885	11,324	125,379	9.0
" 1886	11,858	128,579	9.2
July, 1886	12,116	130,334	9.2

As in America, the narrow gauge system has failed of success in almost all other countries. The *Railroad Gazette* gives the railway gauges in the various countries of the world in 1887 as follows:—

EUROPE.

Germany, Austria, Switzerland, France, Italy, Denmark, The Netherlands, England, Roumania, Turkey	In these ten countries the principal lines have adopted the standard gauge of 4 feet 8½ inches. Lines with a gauge differing from the above are comparatively few.
Ireland	The standard gauge is 5 feet 3 inches.
Spain	The standard gauge is 5 feet 6 inches.
Portugal	The standard gauge is 5 feet 6 inches.
Russia	The standard gauge is 5 feet.
Sweden	About four-fifths of the whole mileage has a gauge of 4 feet 8½ inches. For the balance six different and smaller gauges are in use.
Norway	About two-fifths of the mileage is laid to 4 feet 8½ inches gauge, the other three-fifths to 3 feet 6 inches gauge.

ASIA.

British India	About two-thirds of the mileage is laid to 5 feet 6 inches gauge, the rest with five different gauges varying from 2 to 4 feet.
The Russian Trans-Caucasian Railways . . .	The standard gauge is 5 feet.
Island of Java	About four-fifths of the mileage is laid to 3 feet 6 inches gauge, and the balance to 4 feet 8½ inches gauge.
Japan	The standard gauge is 3 feet 6 inches.

AFRICA.

Egypt	The standard gauge is 4 feet 8½ inches.
Algeria and Tunis . . .	The standard gauge is 4 feet 8½ inches. There are 150 miles of 3 feet 7½ inches gauge.
The English Cape Colonies	The standard gauge is 3 feet 6 inches.

AUSTRALIA.

New South Wales . . .	The standard gauge is 4 feet 8½ inches.
Victoria	The standard gauge is 5 feet 3 inches.
South Australia	Gauges of 5 feet 3 inches and 3 feet 5 inches are adopted.

The *Railroad Gazette* says: "Of the total length of railroads in the world, about 74 per cent is standard gauge (4 feet 8½ inches), including the American differential gauge; 12 per cent wider gauge, and 14 per cent smaller gauge."

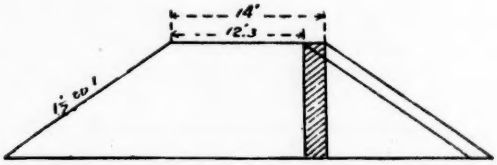
The failure of narrow gauge railways to compete with those of standard gauge is, it must be remembered, largely due to the great inconvenience of trans-shipping goods at connecting points. Where there is already a large mileage of railways having a certain gauge, it is next to impossible to introduce any other gauge with success, unless the new gauge has some extraordinary merits of its own. Trans-shipment of goods from one car to another, implies additional labor, loss of time, loss due to keeping cars standing idle, and damages to goods during trans-shipment. These items add largely to the total cost of transportation per mile, especially when the haul is short. Hence, the mere fact that the narrow gauge is gradually giving way before the steady growth of the 4 feet 8½ inches gauge, does not necessarily prove that the latter is the more economical. In considering the comparative advantages of the narrow gauge and the standard gauge, it is therefore essential that we should entirely disregard the question of the break of gauge.

In order that our comparison may be fair, it is further necessary that we should assume the requirements in regard to the speed, the frequency, the volume, and the nature of the traffic to be hauled, and the

features of the country in which the line is located to be the same in both cases. It is customary for narrow gauge enthusiasts to compare light narrow gauge railways with heavy standard gauge railways, and to arrive at the final conclusion that no standard gauge railways could be constructed and operated as cheaply as narrow gauge railways. Of course, such an argument has no value whatever.

Keeping these conditions for a fair comparison in our mind, let us now examine the various advantages claimed for the narrow gauge.

The first is the reduction in cost of construction, owing to the smaller width of roadway in embankments and cuts. That there is some saving from this source is evident. The question is: How much? Now, the only reason for reducing the width of roadway in the narrow gauge railway is because the distance between the two rails is less than in the standard gauge railway. Hence, we cannot properly reduce the width of roadway more than we reduce the gauge. Suppose the width of roadway on embankment for the standard gauge to be 14 feet, then the corresponding width for the 3 feet gauge will be $14'-(4.'7-3')=$ 12.3 feet. In a level fill with a centre height of 10 feet, the reduction



of the area of the section, and consequently of the amount of earthwork, in the narrow gauge is $\frac{1.7 \times 10}{14 \times 10 + 15 \times 10} = 5.9$ per cent. We can easily see from the figure, that the greater the centre height, the less is the percentage of reduction. Thus with a centre height of 30 feet the earthwork is reduced by only 2.9 per cent. Following is a table showing percentages of reduction of earthwork for various roadbeds and centre heights, due to a reduction of the gauge from 4 feet 8½ inches to 3 feet.

TABLE SHOWING PERCENTAGE OF REDUCTION OF EARTHWORK FOR DIFFERENT ROADBEDS AND CENTRE HEIGHTS WHEN GAUGE IS REDUCED FROM 4 FEET 8½ INCHES TO 3 FEET.

CENTRE HEIGHT.	Width of Roadbed for 4 Feet 8½ Inches Gauge.					
	14′	13′	12′	11′	10′	9′
Feet.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
½	11.5	12.4	13.3	14.5	15.8	17.4
1	10.9	11.7	12.6	13.6	14.8	16.2
2	10.0	10.6	11.3	12.1	13.1	14.2
3	9.2	9.8	10.3	11.0	11.7	12.6
4	8.5	8.9	9.4	10.0	10.6	11.3
5	7.9	8.3	8.7	9.2	9.7	10.3
6	7.4	7.7	8.1	8.5	8.9	9.4
7	6.9	7.2	7.5	7.9	8.3	8.7
8	6.5	6.8	7.1	7.4	7.7	8.1
9	6.2	6.4	6.7	6.9	7.2	7.5
10	5.9	6.1	6.3	6.5	6.8	7.1
12	5.3	5.5	5.7	5.9	6.1	6.3
14	4.9	5.0	5.2	5.2	5.5	5.7
16	4.5	4.6	4.7	4.9	5.0	5.1
18	4.2	4.3	4.4	4.4	4.6	4.7
20	3.9	4.0	4.0	4.1	4.2	4.4
25	3.3	3.3	3.4	3.5	3.6	3.6
30	2.9	2.9	3.0	3.0	3.1	3.1
35	2.5	2.6	2.6	2.7	2.7	2.8
40	2.3	2.3	2.4	2.4	2.4	2.5

The amount of reduction of earthwork in cuts is about the same as in fills. The presence of ditches, however, which makes the necessary width of roadway a little greater, somewhat decreases the percentage of saving.

Since the rate of reduction decreases as the centre height increases, the economy of the narrow gauge on this point is greatest when there are long stretches of light cuts and fills. But as a rule, in such cases, the total amount of earthwork will be small. Hence it follows that the greater the total quantity of earthwork, the less the percentage of saving in earthwork accomplished by reducing the gauge.

For the same reason that the quantity of earthwork is reduced, that of masonry in bridge abutments may be reduced, and in about the same proportion, by the reduction of gauge.

The length of culverts, boxes, and pipes will be less for the narrow gauge than for the standard gauge. Here again the percentage of re-

duction is less, the greater the height of embankment. Assuming the height of culvert as 5 feet, the saving of material in a 15 feet embankment, with the standard gauge roadbed of 14 feet, will be $\frac{1.7}{14+15\times 2}=3.9$ per cent, if we neglect masonry in wing walls, which will considerably diminish the above percentage of saving.

As to ballast, rails, ties, bridges, and trestle works, they must be proportioned according to the weight of the trains that pass over them. These will therefore be referred to after the rolling stock has been considered.

It is claimed that cars of a given capacity can be built lighter and more cheaply for the narrow gauge than for the standard gauge railway; and that, therefore, to haul a given amount of traffic, lighter engines are needed on the former than on the latter. Fairlie says in his address: "The dead weight of trains conveying either passengers or goods is in direct proportion to the gauge on which they run; or, in other words, the proportion of non-paying to paying weight (so far as this is independent of management) is increased exactly as the rails are further apart; because a ton of materials disposed upon a narrow gauge is stronger as regards its carrying power than the same weight when spread over a wider basis." The truth is, however, that there is no such advantage in narrow gauge cars. If the transverse beams of the narrow gauge car are reduced in length, the longitudinal beams must be increased in length, if the capacity of the car is to remain the same. In fact, so far as the weight of the car-body alone is concerned, the advantage is rather on the side of the standard gauge. Of two quadrilaterals of a given area, the one which is the nearer in shape to a square has the smaller perimeter; hence the horizontal section of the standard gauge car, which, with the same capacity, is wider and shorter than the narrow gauge car, is more nearly square, and therefore the walls contain less material than those of the narrow gauge car. As to the weight of the trucks, it is slightly less for the narrow gauge, owing to the shortening of the transverse pieces, such as the axles and bolsters. The load and the weight of the car-body remaining the same, the wheels, journals, bearings, springs and longitudinal side beams cannot properly be reduced in strength or weight simply because the gauge is narrower. Thus we see that the weight of only a few minor parts of the car is affected by the width of gauge. The amount by which the weight of these parts is reduced in consequence of the reduction of the gauge from 4 feet $8\frac{1}{2}$ inches to 3 feet will not probably be as much as one per cent of the total weight of the car.

It may here be added that any car-body that can be placed on narrow gauge trucks can be placed on standard gauge trucks with even greater safety. Hence the difference of weight between narrow gauge and standard gauge cars, if there be any, should not be assumed greater than that which exists in trucks.

If the weight of a car is the same for both gauges, the locomotive that hauls a train loaded with the same amount of goods must have the same tractive force, and therefore the same weight, whether the gauge is 4 feet 8½ inches or 3 feet.

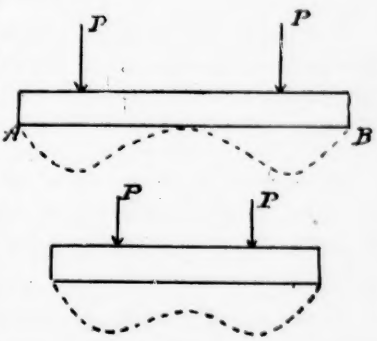
In regard to the cost of rolling stock, there is absolutely no gain in narrowing the gauge. It takes just as much time and labor to construct a car of a given capacity for the narrow gauge as for the standard gauge. The difference, if there be any, lies entirely in the quantity of material, which cannot affect the cost to any perceptible extent. The same is true with regard to locomotives. Locomotives of the same weight cannot be built any more cheaply for the 3 feet gauge than for the 4 feet 8½ inches gauge. This is shown by the following table, taken from Wellington's "Economic Theory of Railway Location":—

COMPARATIVE COST PER TON OF VARIOUS SIZES OF ENGINES FOR BROAD AND NARROW GAUGE.

AMERICAN TYPE — STANDARD GAUGE.

CYLINDERS.	WEIGHT (NET TON).		COST.		
	Total.	On Drivers.	Engine.	Tender.	Per Ton on Drivers.
12 × 22	24.	15.	$5,750	$950	$385
13 × 24	27.	18.	6,000	1,000	333
14 × 24	29.5	19.5	6,250	1,050	321
15 × 24	32.5	22.	6,500	1,100	295
16 × 24	36.	24.5	6,750	1,150	276
17 × 24	38.	25.5	7,000	1,200	275
18 × 24	41.	27.5	7,250	1,250	264
MOGUL TYPE — STANDARD GAUGE.					
16 × 24	37.	32.5	$7,250	$1,150	$223
17 × 24	39.	34.5	7,500	1,200	217
18 × 24	42.	37.	7,750	1,300	209
19 × 24	45.	40.	8,000	1,350	200
CONSOLIDATION TYPE — STANDARD GAUGE.					
20 × 24	53.	46.	$9,250	$1,400	$201
21 × 24	59.	52.	9,750	1,400	188
AMERICAN TYPE — NARROW GAUGE.					
10 × 16	16.5	11.	$4,750	$750	$432
11 × 16	18.	12.	5,000	775	417
12 × 16	19.5	13.	5,250	800	404
13 × 16	22.5	15.5	5,500	850	355
14 × 16	24.	16.5	5,750	900	357
MOGUL TYPE — NARROW GAUGE.					
11 × 16	17.5	14.5	$5,250	$800	$362
12 × 16	20.	16.5	5,500	850	334
13 × 16	23.	19.5	5,750	900	295
14 × 16	25.	21.5	6,000	950	278
15 × 16	28.	24.5	6,250	1,000	255
CONSOLIDATION TYPE — NARROW GAUGE.					
15 × 18	28.	24.	$6,750	$950	$282
16 × 18	34.	29.	7,250	1,000	250

Since the weight of a train is thus the same for both gauges, it follows that the rails, spikes, frogs, etc., must have the same size and strength in both cases. The size of cross-ties may be different; for the stiffness of a tie increases as the distance between the two rails is reduced. Considering the tie as an inverted beam uniformly loaded and supported at the points under each rail, we can see that its stiffness varies directly as the cube of its depth, and inversely as the cube of the distance between the two rails, approximately. Hence if a thickness of 6 inches is required for the standard gauge tie, the thickness required for the narrow gauge tie of the same stiffness is $\sqrt[3]{\frac{6^3 \times 3^3}{4.7^3}} = 3.83$ inches. But in determining the size of cross-ties there is another element which we must take into account, namely, the bearing surface. If the tie were perfectly stiff, the weight P on the wheels would be uniformly distributed over the area AB, and the intensity of pressure on the ballast would be $\frac{2P}{\text{area } AB}$. In that case the tie for the narrow gauge railway should have the same bearing area as that for the standard gauge railway. But in practice the tie is not perfectly rigid, and the greatest pressure occurs directly under the rails. Therefore, if we diminish the gauge, and cut off both ends of the tie, the effect may be, within a certain limit, chiefly to increase the pressure near the middle of the tie; and though the average pressure per unit of area is increased, the maximum pressure possibly remains nearly the same. Hence cross-ties for the narrow gauge may, perhaps, be made somewhat shorter than those for the standard gauge, though it is impossible to tell just how much. If they are too short, not only is the pressure per square inch increased, but the stiffness is decreased, on account of the increase of pressure near the middle. It must also be remembered that any reduction of the length of ties diminishes the stability of the track, and consequently increases the track labor required. According to the *Railroad Gazette*, the dimensions of cross-ties on different narrow gauge railways of America in 1878 were as shown in the following table:—



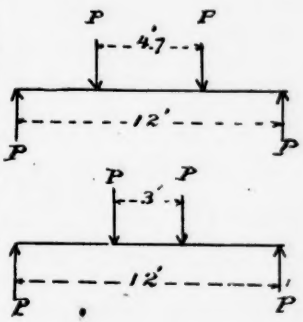
Dimensions of Ties.	No. of Railroads using them.	Dimensions of Ties.	No. of Railroads using them.
4″ × 6″ 4′ 6″ long . . .	1	6″ × 8″ 6′ long	8
4″ × 6″ 5′ " . . .	1	7″ × 7″ 6′ "	2
5″ × 6″ 5′ 4″ " . . .	1	( ) × ( ) 6′ 3″ "	1
5″ × 7″ 5′ 6″ " . . .	1	6″ × 8″ – 5″ × 6″ 6 6″ "	2
5″ × 8″ 5′ 6″ " . . .	1	( ) × ( ) 7′ "	1
4″ × 7″ 6′ " . . .	1	5″ × 8″ 6′ "	1*
5″ × 6″ 6′ " . . .	3	5″ × 6″ 6′ "	1*
5″ × 7″ 6′ " . . .	4	( ) × ( ) 6′ 6″ "	1*
6″ × 6″ 6′ " . . .	8	6″ × 7″ 7′ "	2*
5″ × 8″ 6′ " . . .	5	6″ × 8″ 7′ 6″ "	1*
6″ × 7″ 6′ " . . .	7	5″ × 6″ 7′ 8″ "	1*

* 3′ 6″ gauge; all the others 3′ gauge.

The cross-ties being shorter, the width of the ballast may be reduced. But its thickness should not be reduced for the obvious reason that the requirements in regard to the solidity of the track and facility of drainage are not affected by a change in the gauge. Suppose the ballast to be one foot thick, and sloped away from the ends of the ties at the rate of $1\frac{1}{2}$ to 1; then, by reducing the gauge from 4 feet $8\frac{1}{2}$ inches to 3 feet, and with it the length of the ties from 8 feet to 6 feet 6 inches, the material for ballast is diminished by $\frac{1.5}{(8+1.5)}=$ 16 per cent.

As to bridges, if the loads remain the same, no saving of material in the main trusses will result from the reduction of the gauge. Besides, it is a fact that the cost of constructing a bridge is very little affected by a slight difference in the loads that pass over it. The only advantage, therefore, that can be claimed for the narrow gauge on this point is that the car-body being narrower than on the standard gauge the distance between two trusses in through bridges may be reduced, and that on this account there will be saving of material in floor beams. But it is evident that this saving will be scarcely worth considering. Besides, it is entirely practicable to place a narrow gauge car-body on standard gauge trucks. If that is done, the width of bridges need no longer be made greater for the 4 feet $8\frac{1}{2}$ inches gauge than for the 3 feet gauge, and the only advantage of the narrow gauge in regard to bridges disappears. On the other hand, there is a positive economy on the part of the standard gauge, because of the fact that the maximum moment in any beam supported at two ends decreases as the loads are placed further from the middle. Let P be the weight that falls on the floor

beam under each rail. Then for the 4 feet 8½ inches gauge the maximum moment in the floor beam is $P \times 3.65 = 3.65P$. For the 3 feet gauge the maximum moment is $P \times 4.5 = 4.5P$. Thus the maximum moment in the floor beam for the 4 feet 8½ inches gauge is but four-fifths of that for the 3 feet gauge, supposing the stringers to be directly beneath the rails. At all events it is certain that, with the same loads, there is no advantage in the narrow gauge in regard to the cost of bridges; and the same remark applies to trestle works.



It is claimed that curve resistance is much less on narrow gauge railways than on standard gauge railways; in fact, this is considered by many narrow gauge advocates as the chief advantage of their system. Let us inquire why and how much the curve resistance is reduced if the gauge is made narrower. Resistance due to curvature arises from three causes; namely, the pressure of flange against rail, the slipping of wheel laterally, and the slipping of wheel longitudinally. Of these three elements of resistance the first two are independent of the gauge. Therefore we have to consider only the longitudinal slipping of wheels.

On any curve, the outside rail being longer than the inside one, it is evident that when a train is running around it either the outside wheels of the cars have to slip forward, or the inside wheels have to slip backward. It does not matter which actually takes place. We will here suppose that only the outside wheels slip. The distance through which the wheels slip while the car travels completely around a circle will be $4.'7 \times 2\pi$ in the standard gauge, and $3' \times 2\pi$ in the narrow gauge. The slipping of wheels while the car travels 100 feet of one-degree curve will be

$$4.'7 \times 2\pi \div 360 = .082 \text{ feet for the standard gauge,}$$
$$3' \times 2\pi \div 360 = .052 \text{ feet for the narrow gauge.}$$

Supposing the coefficient of friction to be ¼, we have train resistance per ton of the weight on the wheels that slip as follows: —

$$2000 \times \tfrac{1}{4} \times \frac{.082}{100} = .410 \text{ lbs., for standard gauge,}$$

$$2000 \times \tfrac{1}{4} \times \frac{.052}{100} = .260 \text{ lbs., for narrow gauge.}$$

Since only one-half of the total weight of the car rests on the outside wheels, resistance per ton of the total weight of the car is:—

$.410 \times \frac{1}{2} = .205$ lbs., for standard gauge,
$.260 \times \frac{1}{2} = .130$ lbs., for narrow gauge.

For a two-degree curve the resistance will be double the resistance for a one-degree curve, for a three-degree curve, three times, and so on for any other curve. The average total resistance due to a one-degree curve, for the standard gauge, being about one pound per ton, the proportion that the curve resistance is reduced by narrowing the gauge from 4 feet $8\frac{1}{2}$ inches to 3 feet is $\frac{.205-.130}{1} = 7.5$ per cent of the total curve resistance. If we take into account the total train resistance, including rolling friction, this difference in curve resistance becomes a very trifling matter. This may be made clear by the following table, showing the comparative resistance of trains on different curves and grades, for the standard gauge and for the narrow gauge. Train resistance on a tangent is taken as 8 pounds per ton, and is considered to increase by 1 pound per ton for each degree of curve up to a 10° curve, above which it is considered to increase by $\frac{1}{2}$ pound per ton for each degree of curve.

Table Showing Resistance in Lbs. per Ton for Different Curves and Grades.

Grade per Cent.	Degree of Curve.															
	0°		1°		2°		3°		4°		5°		6°		7°	
	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
0	8	8	9	8.92	10	9.85	11	10.77	12	11.70	13	12.62	14	13.55	15	14.47
0.1	10	10	11	10.92	12	11.85	13	12.77	14	13.70	15	14.62	16	15.55	17	16.47
0.2	12	12	13	12.92	14	13.85	15	14.77	16	15.70	17	16.62	18	17.55	19	18.47
0.3	14	14	15	14.92	16	15.85	17	16.77	18	17.70	19	18.62	20	19.55	21	20.47
0.4	16	16	17	16.92	18	17.85	19	18.77	20	19.70	21	20.62	22	21.55	23	22.47
0.5	18	18	19	18.92	20	19.85	21	20.77	22	21.70	23	22.62	24	23.55	25	24.47
0.6	20	20	21	20.92	22	21.85	23	22.77	24	23.70	25	24.62	26	25.55	27	26.47
0.7	22	22	23	22.92	24	23.85	25	24.77	26	25.70	27	26.62	28	27.55	29	28.47
0.8	24	24	25	24.92	26	25.85	27	26.77	28	27.70	29	28.62	30	29.55	31	30.47
0.9	26	26	27	26.92	28	27.85	29	28.77	30	29.70	31	30.62	32	31.55	33	32.47
1.0	28	28	29	28.92	30	29.85	31	30.77	32	31.70	33	32.62	34	33.55	35	34.47
1.1	30	30	31	30.92	32	31.85	33	32.77	34	33.70	35	34.62	36	35.55	37	36.47
1.2	32	32	33	32.92	34	33.85	35	34.77	36	35.70	37	36.62	38	37.55	39	38.47
1.3	34	34	35	34.92	36	35.85	37	36.77	38	37.70	39	38.62	40	39.55	41	40.47
1.4	36	36	37	36.92	38	37.85	39	38.77	40	39.70	41	40.62	42	41.55	43	42.47
1.5	38	38	39	38.92	40	39.85	41	40.77	42	41.70	43	42.62	44	43.55	45	44.47
1.6	40	40	41	40.92	42	41.85	43	42.77	44	43.70	45	44.62	46	45.55	47	46.47
1.7	42	42	43	42.92	44	43.85	45	44.77	46	45.70	47	46.62	48	47.55	49	48.47
1.8	44	44	45	44.92	46	45.85	47	46.77	48	47.70	49	48.62	50	49.55	51	50.47
1.9	46	46	47	46.92	48	47.85	49	48.77	50	49.70	51	50.62	52	51.55	53	52.47
2.0	48	48	49	48.92	50	49.85	51	50.77	52	51.70	53	52.62	54	53.55	55	54.47

Grade per Cent.	Degree of Curve.															
	8°		9°		10°		15°		20°		25°		30°		35°	
	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N
0	16	15.40	17	16.32	18	17.25	20.5	19.37	23	21.5	25.5	23.62	28	25.75	30.5	27.87
0.1	18	17.40	19	18.32	20	19.25	22.5	21.37	25	23.5	27.5	25.62	30	27.75	32.5	29.87
0.2	20	19.40	21	20.32	22	21.25	24.5	23.37	27	25.5	29.5	27.62	32	29.75	34.5	31.87
0.3	22	21.40	23	22.32	24	23.25	26.5	25.37	29	27.5	31.5	29.62	34	31.75	36.5	33.87
0.4	24	23.40	25	24.32	26	25.25	28.5	27.37	31	29.5	33.5	31.62	36	33.75	38.5	35.87
0.5	26	25.40	27	26.32	28	27.25	30.5	29.37	33	31.5	35.5	33.62	38	35.75	40.5	37.87
0.6	28	27.40	29	28.32	30	29.25	32.5	31.37	35	33.5	37.5	35.62	40	37.75	42.5	39.87
0.7	30	29.40	31	30.32	32	31.25	34.5	33.37	37	35.5	39.5	37.62	42	39.75	44.5	41.87
0.8	32	31.40	33	32.32	34	33.25	36.5	35.37	39	37.5	41.5	39.62	44	41.75	46.5	43.87
0.9	34	33.40	35	34.32	36	35.25	38.5	37.37	41	39.5	43.5	41.62	46	43.75	48.5	45.87
1.0	36	35.40	37	36.32	38	37.25	40.5	39.37	43	41.5	45.5	43.62	48	45.75	50.5	47.87
1.1	38	37.40	39	38.32	40	39.25	42.5	41.37	45	43.5	47.5	45.62	50	47.75	52.5	49.87
1.2	40	39.40	41	40.32	42	41.25	44.5	43.37	47	45.5	49.5	47.62	52	49.75	54.5	51.87
1.3	42	41.40	43	42.32	44	43.25	46.5	45.37	49	47.5	51.5	49.62	54	51.75	56.5	53.87
1.4	44	43.40	45	44.32	46	45.25	48.5	47.37	51	49.5	53.5	51.62	56	53.75	58.5	55.87
1.5	46	45.40	47	46.32	48	47.25	50.5	49.37	53	51.5	55.5	53.62	58	55.75	60.5	57.87
1.6	48	47.40	49	48.32	50	49.25	52.5	51.37	55	53.5	57.5	55.62	60	57.75	62.5	59.87
1.7	50	49.40	51	50.32	52	51.25	54.5	53.37	57	55.5	59.5	57.62	62	59.75	64.5	61.87
1.8	52	51.40	53	52.32	54	53.25	56.5	55.37	59	57.5	61.5	59.62	64	61.75	66.5	63.87
1.9	54	53.40	55	54.32	56	55.25	58.5	57.37	61	59.5	63.5	61.62	66	63.75	68.5	65.87
2.0	56	55.40	57	56.32	58	57.25	60.5	59.37	63	61.5	65.5	63.62	68	65.75	70.5	67.87

S = Standard gauge. N = Narrow gauge.

The table shows that the effect of the gauge on curve resistance is very small, scarcely worth being considered. Let us, however, examine what the consequence of this little increase in curve resistance will be. 1st. The amount of fuel required to haul a given traffic will be increased. 2d. The wear and tear of rails and wheels will be increased. 3d. The maximum train load must be diminished on account of this extra resistance. Of these three effects the first two are so insignificant that we may entirely neglect them. It is only in the case of the sharpest curves, which limit the train load, that we have to consider the difference of curve resistance between the two gauges; that is, if we are going to consider it all. Even in that case it is not curve resistance alone that is to be taken into consideration, but it is curve resistance combined with grade resistance. On such roads as the New York Central the train load is limited by the maximum curve alone; but this is rather an exceptional case, and as a rule the train load is limited by the combination of curve and grade at the same point, which causes the maximum resistance. If the maximum curve happens to come at the same place with some heavy grade, it is practicable, in nine cases out of ten, to keep the total resistance at that place equal to that due the maximum grade alone, by reducing the grade on the curve. As we have seen above, the difference of resistance per degree of curve between the standard and the narrow gauge is .075 lbs. per ton, which is equal to the resistance due to a .004 per cent grade. Hence, in order to make resistance on the standard gauge equal to that on the narrow gauge, we have only to reduce the grade by .004 per cent for every degree of curve. To do this will not require much outlay even when the curve is very sharp.

Reduction of work and material in excavating and lining tunnels is often brought forward as an advantage of the narrow gauge. But if, as has been suggested above, we place the narrow gauge car-body on standard gauge trucks, then tunnels need no longer be wider or higher for the standard than for the narrow gauge railroad. Moreover, whatever saving there is on this point cannot have much importance, for the cost of tunnels does not generally constitute a large item in the cost of construction of a railway; and even when it does, it varies far less than in proportion to the width and height of the tunnels.

Saving in the cost of right of way on the narrow gauge railway is so small an item that it is not worth while to consider it here.

From the preceding it can be seen that there are really no great advantages in reducing the gauge, the only advantage, in fact, being some small reduction in the cost of earthwork, ballast, ties, and masonry. In order to get at some idea as to how many dollars this reduction

amounts to, the following estimate is given of the comparative cost of construction of a railway in Japan, with the 3 feet 6 inches gauge and with the standard gauge. The original estimate for the gauge of 3 feet 6 inches was made by a Japanese engineer. The line is about 32 miles long.

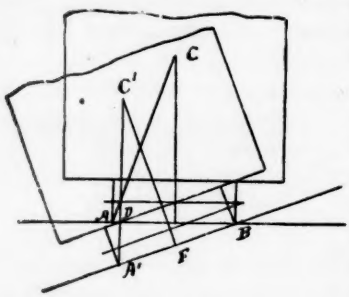
Items.	Cost.	Percentage of Increase by Increase of Gauge to 4′ 8½″.	Increase of Cost due to the Increase of Gauge to 4′ 8½″.
Surveying	$2,257.50	Unaffected.	
Superintending the works	20,000.00	"	
Right of way	32,380.00	"	
Cuts	25,220.00	8 per cent.	$2,017.60
Fills	71,760.00	8 "	5,740.80
Retaining walls	9,000.00	8 "	720.00
Changing course of roads	2,210.00	Unaffected.	
Changing course of streams	8,190.00	"	
Road crossings	600.00	"	
Fences	990.00	"	
Bridges	35,940.00	"	
Culverts, boxes, and pipes	42,500.00	8 per cent.	3,400.00
Ballast	17,875.00	16 "	2,860.00
Rails, spikes, etc.	217,030.00	Unaffected.	
Switches and frogs	5,000.00	"	
Cross-ties (at 22 cents)	15,620.00	25 per cent.	3,905.00
Mile-posts, signal posts, etc.	650.00	Unaffected.	
Track laying	2,000.00	"	
Stations	23,650.00	"	
Machine shops	40,000.00	"	
Other buildings	5,000.00	"	
Transporting materials	15,000.00	"	
Train expenses (in construction)	5,000.00	"	
Machines	10,000.00	"	
Rolling stock	170,000.00	"	
Salaries, office expenses, etc.	10,000.00	"	
Telegraph equipment	6,450.00	"	
In reserve	50,000.00	"	
	$844,322.50		$18,643.40

Increase of cost, $18,643.40 = 2.2 per cent of $844,322.50.

Having satisfied ourselves that none of the advantages claimed for the narrow gauge are of much importance, we will now proceed to examine some of its disadvantages.

The first disadvantage is, that the distance between the two supports of the car being shorter, the car is less stable than on the standard gauge railway; so that the tendency of the train to be upset on uneven track

and on curves is increased. Let the height of centre of gravity of the narrow gauge car above the rails be four feet; then that of the standard gauge car with the same wheels and the same car-body will also be four feet.



On tangent track the car is going to be overturned when the level of the track is so much disturbed that a vertical line through the centre of gravity of the car passes just outside the point of contact of the wheel with the rail. From the similarity of the triangles $A'CF$ and $A'BD$, we get the difference of level between two rails necessary to overturn the car.

$$DA' = \frac{A'F \times A'B}{CA'} = \frac{\frac{1}{2}\text{ gauge} \times \text{gauge}}{\sqrt{4^2 + (\frac{1}{2}\text{ gauge})^2}}.$$

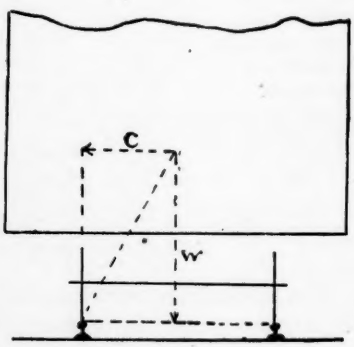
For the 3 feet gauge,

$$DA' = \frac{1.5 \times 3}{\sqrt{16 + 2.25}} = 1.05 \text{ ft.}$$

For the 4 feet $8\frac{1}{2}$ inches gauge,

$$DA = \frac{2.35 \times 4.7}{\sqrt{16 + 5.52}} = 2.4 \text{ ft.}$$

Thus, on the narrow gauge railway a difference of a little more than a foot between the elevations of the two rails is sufficient to upset the train, while on the standard gauge railway one rail must be nearly two feet and a half lower than the other to obtain the same result.



In order that the car may be overturned on a curve, the resultant of the centrifugal force and the weight of the car must pass outside the point of contact of wheel and rail. Taking as an example the simple case of a level track with no superelevation, this occurs when

$$\frac{\text{weight} = W}{\text{cent. force} = C} = \frac{\text{cent. gravity above track} = h}{\text{half gauge} = \frac{1}{2}l}.$$

But centrifugal force is equal to $\frac{Wv^2}{gr}$. Therefore we have

$$\frac{grW}{Wv^2} = \frac{2h}{l};$$

$$\therefore v = \sqrt{\frac{lgr}{2h}}.$$

Therefore the maximum safe speed on a given curve without super-elevation for the narrow gauge is to that for the standard gauge as $\sqrt{3}$ is to $\sqrt{4.7}$, or as 1.73 is to 2.17, the difference being about 16 per cent in favor of the standard gauge.

The unstableness of the narrow gauge car is lessened to some extent by making the diameter of the wheels smaller. But this increases the resistance due to axle friction, and consequently the total train resistance. Other things being equal, the resistance due to axle friction varies inversely as the diameter of the wheel, and directly as the diameter of the journal. The dimension of the latter is determined by the weight that it has to support. Therefore if the load and the weight of the car-body are unchanged, the journal must be of the same size for the narrow as for the standard gauge car. The coefficient of journal train resistance is

$$C = \frac{\text{coefficient of friction} \times \text{diameter of journal}}{\text{diameter of wheel}}.$$

If the diameter of wheel for the standard gauge is 33 inches, and that for the narrow gauge 24 inches, and the diameter of journal $3\frac{3}{4}$ inches for both gauges; then assuming the coefficient of friction to be .02, we have journal train resistance in lbs. per ton as follows: —

For the standard gauge,

$$R = 2000 \times .02 \times 3\tfrac{3}{4} \times \tfrac{1}{33} = 4.6 \text{ lbs.};$$

For the narrow gauge,

$$R = 2000 \times .02 \times 3\tfrac{3}{4} \times \tfrac{1}{24} = 6.25 \text{ lbs.}$$

This resistance is therefore about 35 per cent greater for the narrow gauge than for the standard gauge. Moreover, the reduction of the wheel diameter to 24 inches in the narrow gauge car is by no means sufficient to give it the same stability as that of the standard gauge car with the wheel diameter of 33 inches.

Thus, in order that the narrow gauge car may have the same stability as the standard gauge car, the resistance due to journal friction must be greatly increased. On the other hand, if we wish to make the resistance due to journal friction of the narrow gauge car the same as

that of the standard gauge car, we are obliged to decrease the stability of the car beyond safety. The result is that trains cannot with safety be run on narrow gauge railways at as high speed as on standard gauge railways; and, with the same speed, it requires more tractive power to haul a given traffic on narrow gauge railways than on standard. Hence it follows that the capacity of a railway is reduced by reducing the gauge.

In order that a car should be stable, not only its height, but its width must have a certain proportion to the gauge. Generally the width of a car cannot properly be made much more than twice the gauge. Hence, narrow gauge cars of a given capacity must be longer than standard gauge cars of the same capacity. To haul a given traffic, therefore, the narrow gauge railway has to use a longer train than the standard gauge railway. If the standard gauge railway requires a train 1,000 feet long to haul a certain traffic, the narrow gauge railway will, in order to do the same work, require a train somewhat longer than $1{,}000 \times \frac{4.7}{3} = 1{,}560$ feet, the additional length depending on the relative heights of cars in the two systems. Increase in the length of trains necessitates the provision of longer sidings, and consequently increases the cost of construction.

Since the vertical and transverse dimensions of the rolling stock must be proportioned according to the gauge, it follows that locomotives of a given weight must be made longer for the narrow gauge than for the standard gauge. Hence, the wheel-base of the narrow gauge locomotive with a given tractive power must be longer than that of the standard gauge locomotive with the same tractive power. The wheel-base being longer, the narrow gauge locomotive will have more difficulty in passing around curves than the standard gauge locomotive.

On account of the smaller stability of rolling stock, the track ought to be kept in better condition on the narrow gauge railway than on the standard. This will require a considerable amount of care and labor; especially since on the narrow gauge railway, the track itself lacks stability, on account of the reduced dimensions of ties and ballast. The late Baron Von Weber, who made extensive observations of the principal narrow gauge railways of Europe says: "Nowhere has the maintenance of the narrow gauge track proved, in practice, to be cheaper than that of the standard gauge, very often dearer; on the average always dearer, when the quantity moved is taken into consideration."

From what precedes, we may conclude that it costs very nearly the same to build a narrow gauge railway as to build one of the standard

gauge; and in regard to the operation, the narrow gauge has no advantage over the standard, but on the contrary, it has several disadvantages —always provided that the requirements as to the bulk, speed, and nature of the traffic are the same for both systems. It is only when traffic is small, and speedy transportation is not required, that a narrow gauge railway can be desirable. When a dozen or more daily trains are regularly run, and some of them at a speed of from 30 to 40 miles an hour, the standard gauge is decidedly preferable. The amount of traffic and the required speed of transportation have been increasing, and will increase hereafter. So, if ever in the future there be a necessity of changing the standard railway gauge, the new standard will be, in all probability, a broader gauge, and not a narrower gauge than the present standard. A country in which the railway is a comparatively new thing, and which is completely isolated from other countries having a large mileage of 4 feet 8½ inches gauge railways, affords the best opportunity for the narrow gauge to prosper. But even then we should take into consideration future growth of the traffic in the country, and take care not to reduce the gauge so much as to make the railways utterly incompetent to meet the requirements of the increased traffic in the future. It may therefore be safely concluded, that to reduce the gauge for the simple sake of saving in the cost of construction, is the last thing the engineer should do.